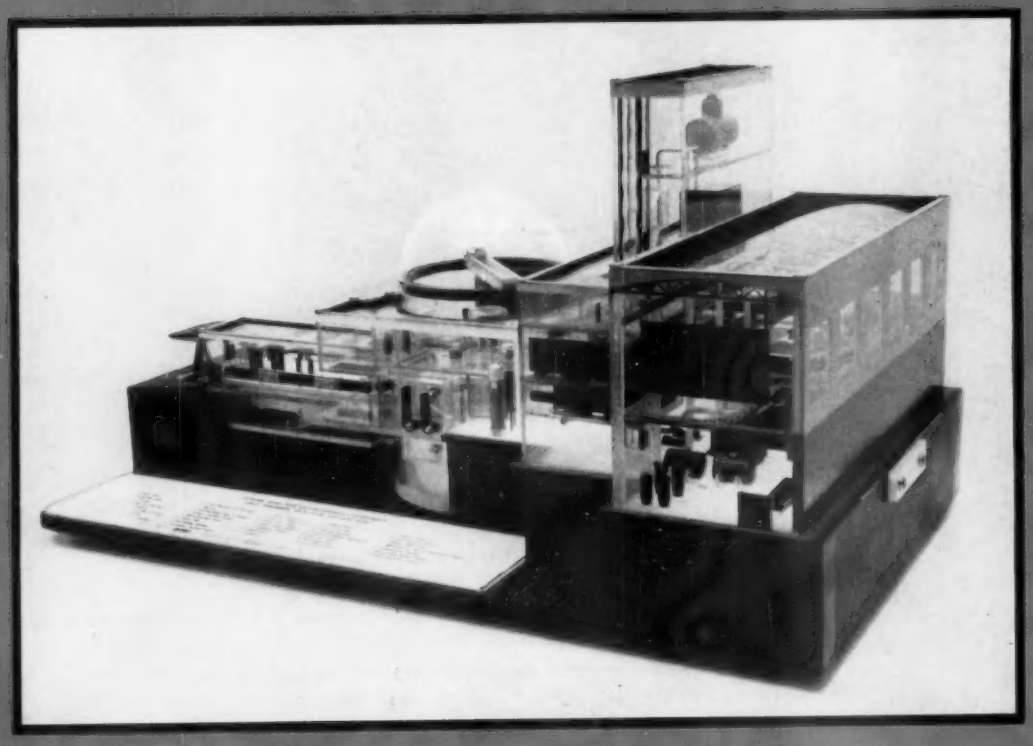
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

January 1958



Model of the Enrico Fermi plant of the Power Reactor Development Co. which will house a 100,000 kw fast breeder reactor

Portland Station Features

Power Practices in 1957

Circulating Water Systems

Stoker Operation

COMBUSTION'S

SCHEDULE OF

"Main Events"

FOR

Dedication of World's Large
Research, Development and
C-E's $15,000,000 Nuclear
1955; construction comple

Construction of Nuclear Sub
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Shipment of Largest and Mo
Reactor vessel for Enrico

Completion of Manufacture o
5000 pounds per square in

Engineering and Partial Man
First boiler ordered to serv

Completion of Installation of
Temperature Package Boile
Two completely shop-assen
per hour, and one to operate

These are some of the achievements which will maintain Combustion's leadership in 1958 in its major field – the creation and building of advanced designs of equipment for the generation of power or heat from conventional or nuclear fuels.

And, in another significant area, Combustion expects to set a new record this year – *the largest volume of shipments and billings in its history.*

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

C-E

C-136

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT: NUCLEAR REACTORS: PAPER MILL EQUIPMENT: PULVERIZERS: FLASH DRYING EQUIPMENT: PRESSURE VESSELS: SOIL PIPE

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ROBERT D. TAFT
Business Manager

JOSEPH C. McCABE
Editor

GLENN R. FRYLING
Associate Editor

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BPA

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COMBUSTION'S

SCHEDULE OF

"Main Events"

FOR 58

Dedication of World's Largest, Privately Owned, Integrated Facilities for Nuclear Research, Development and Manufacture

C-E's $15,000,000 Nuclear Division at Windsor, Connecticut. Ground broken December 1955; construction completed in late '57; dedication in Spring of '58.

Construction of Nuclear Submarine Prototype

At C-E Nuclear Division, Windsor, Connecticut. First nuclear submarine prototype to be designed and built at other than AEC-owned facilities.

Shipment of Largest and Most Complex Nuclear Vessel Built to Date

Reactor vessel for Enrico Fermi Nuclear Power Station.

Completion of Manufacture of World's Highest Pressure, Highest Temperature Boiler

5000 pounds per square inch; 1200 deg. Fahr.

Engineering and Partial Manufacture of World's Largest Boiler

First boiler ordered to serve a turbine generator with a capacity as high as 500,000 kw.

Completion of Installation of World's Highest Capacity, Highest Pressure, Highest Temperature Package Boilers

Two completely shop-assembled boilers, one with a capacity of 100,000 pounds of steam per hour, and one to operate at a pressure of 1800 pounds per square inch and 1050 deg. Fahr.

These are some of the achievements which will maintain Combustion's leadership in 1958 in its major field — the creation and building of advanced designs of equipment for the generation of power or heat from conventional or nuclear fuels.

And, in another significant area, Combustion expects to set a new record this year — *the largest volume of shipments and billings in its history.*

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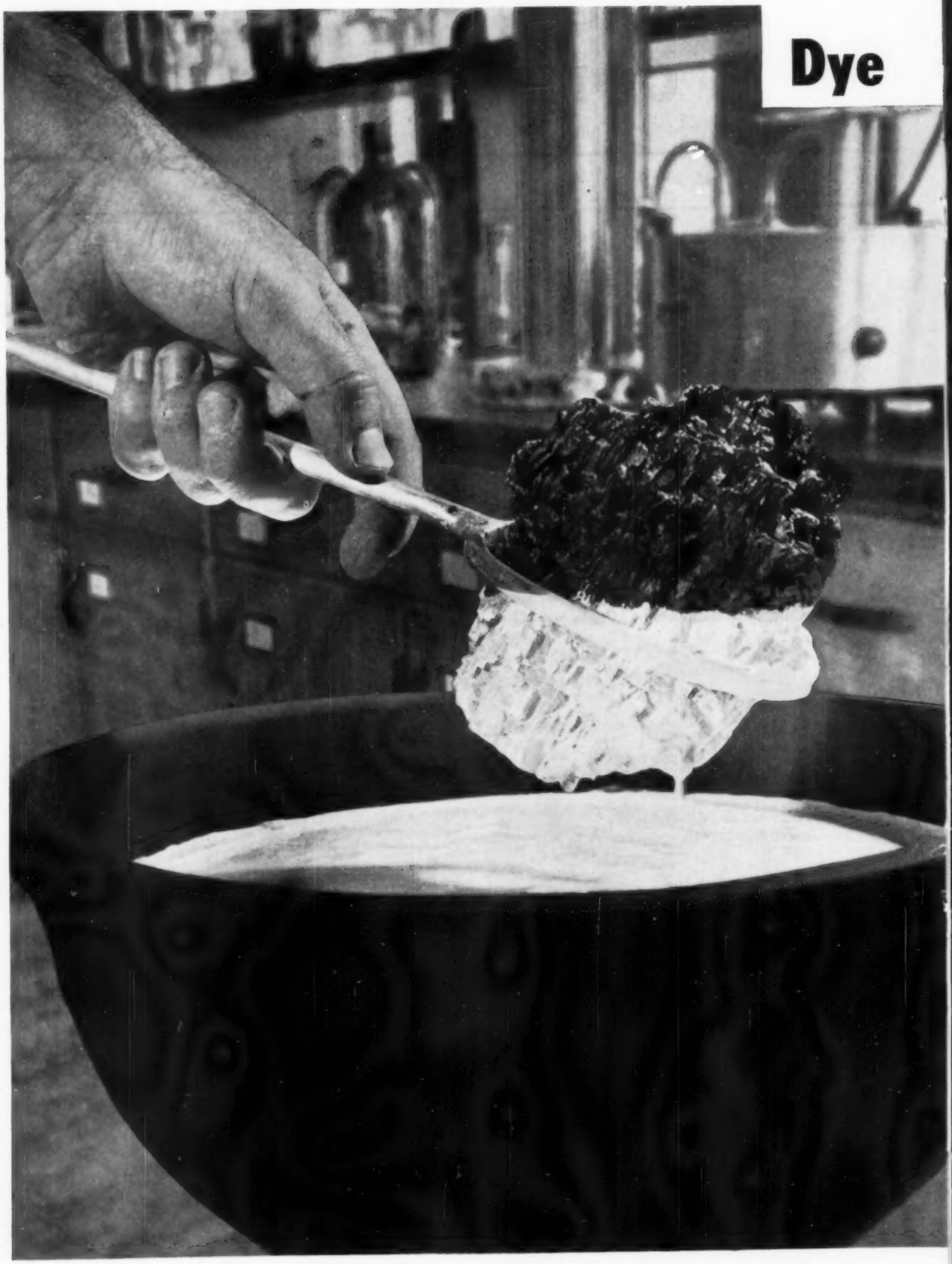

Dye

maker brightens fuel cost picture

Burning coal at Toms River-Cincinnati saves 20% on fuel costs, permits clean steam generation

The Toms River-Cincinnati Chemical Corp. plant in Toms River, N.J. is the most modern plant of its kind in the world. Producing vat dyestuffs requires a large dependable steam supply for chemical processes and heating purposes. To fill these requirements, the power plant at Toms River-Cincinnati is as up-to-date and efficient as the general plant itself. The fuel used for steam generation is *coal* because, on the basis of cost per thousand pounds of steam, the nearest competitive fuel costs 20% more than coal. In addition, thanks to automatic operation and modern equipment, the power plant meets the rigid standards of cleanliness required in such manufacturing operations.

Facts you should know about coal

Not only is bituminous coal the lowest-cost fuel in most industrial areas, as in the case of Toms River-Cincinnati, but up-to-date coal burning equipment can give you 10% to 40% more steam per dollar. Today's automatic equipment pares labor costs and eliminates smoke problems. And vast coal reserves plus mechanized production methods mean a constantly plentiful supply of coal at stable prices.

Technical advisory service

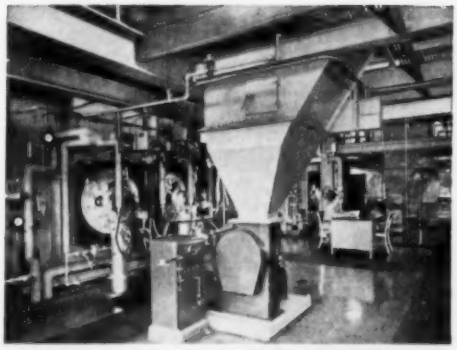
The Bituminous Coal Institute offers a free technical advisory service on industrial fuel problems. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to the address below. Or send for our case history booklet, complete with data sheets. You'll find it informative.

Consult an engineering firm

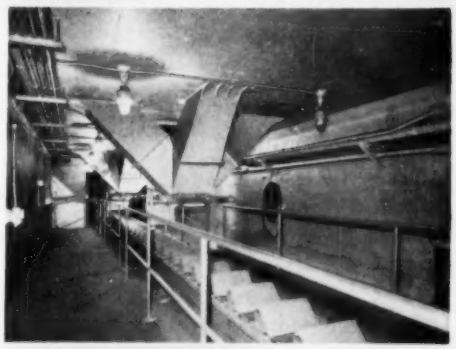
If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—will effect great savings for you in efficiency and fuel economy over the years.

BITUMINOUS COAL INSTITUTE

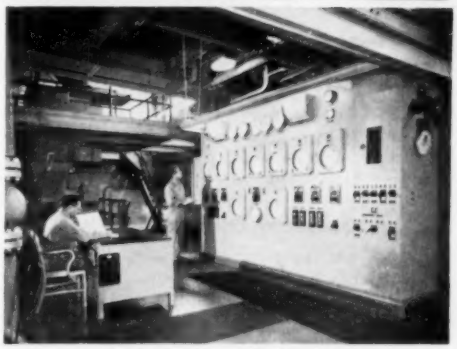
Southern Building • Washington 5, D. C.



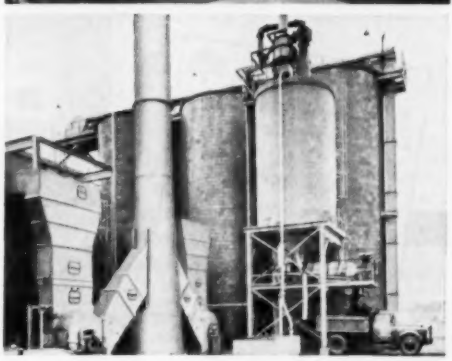
View of boiler room showing both 50,000 lbs. hr. boilers, by Riley Stoker Corp. Each has two burners. Center foreground is automatic weigh scale, by Richardson Scale Co., which receives coal through hopper from live storage bin and passes it to coal feeder. Coal is fed to Riley Pulverizer in basement, then blown back up to burners.



Close-up of Gifford-Wood Roundabout Bucket Conveyor beneath coal storage silos. Transversing feeder-car is used when coal is emptied from silo and conveyed to live storage bin.



Automatic combustion control and instrument panel by Bailey Meter Co.



Fly ash being loaded on truck through a dustless rotary unloader. Fly ash is collected by Prat-Daniel Mechanical Precipitators. A pneumatic ash collecting system by United Conveyor (with tie-ins under air heater and at base of stack) removes it to this 20-ton ash silo. In the rear are three 330-ton coal silos.

This Bailey Meter Control System is —

Saving Fuel at Appliance Park

★ General Electric Company at its Appliance Park Boiler House, Louisville, Ky. has found that Bailey Controls help to save fuel by continuously maintaining desired operating conditions.

With a Bailey-engineered control system you can count on a high output of available energy per unit of fuel.

Here's why:

1. Suitable Equipment

When you receive equipment recommendations from a Bailey Engineer his selections come from a complete line of well-engineered and carefully tested products.

2. Seasoned Engineering Experience

Your local Bailey Engineer brings you seasoned engineering experience based on thousands of successful installations involving problems in measurement, combustion, and automatic control.

3. Direct Sales-Service—close to you

For your convenience and to save time and travel expense there's a Bailey District Office or Resident Engineer in or close to your industrial community.

For greater fuel savings, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're glad to stand on our record.

A128-1

FORMULA
for Cutting Steam Costs

\+ Bailey Design
\+ Bailey Engineering
\+ Bailey Service

= Greater Savings per Fuel Dollar

BAILEY
METER COMPANY
1025 IVANHOE ROAD
CLEVELAND 10, OHIO
Complete Controls for Steam Plants

BAILEY METERS
Controls for
COMBUSTION
FEED WATER
TEMPERATURE
PRESSURE
LIQUID LEVEL
FEED PUMPS

Valves for Power Plants

Fig. 1314 A—1500-Pound Integral bonnet steel "Y" Valve.

Fig. 19003—Powell Steel Pressure Seal Gate Valve for 900 pounds W.S.P.

Fig. 375—Bronze Gate Valve for 200 pounds W.S.P. Union bonnet, inside screw rising stem.

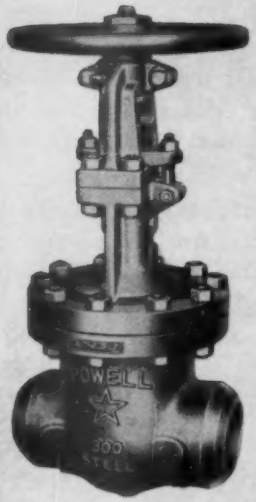


Fig. 3003 WE—Steel Gate Valve for 300 pounds. Outside screw rising stem and yoke.

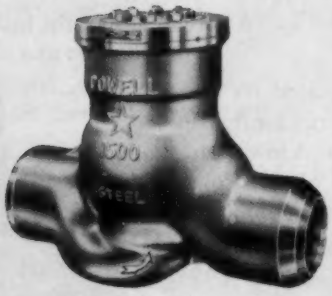


Fig. 11365—Steel Pressure Seal Horizontal Lift Check Valve for 1500 pounds.

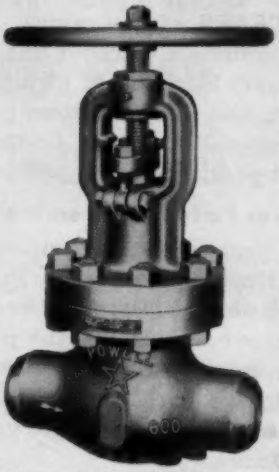


Fig. 6031 WE—600-Pound Steel Globe Valve for steam service. Outside screw stem and yoke.

POWELL...

world's largest family of valves

FOR EVERY FLOW CONTROL PROBLEM Powell offers more kinds or types of valves, available in the largest variety of metals and alloys, to handle every flow control requirement. Your local valve distributor will be glad to tell you all about them. Or write to us for the full facts.

THE WM. POWELL COMPANY • *Dependable Valves Since 1846* • **Cincinnati 22, Ohio**

Eastern Public Utility Installs Two More Koppers Electrostatic Precipitators to Remove Fly Ash

Major Utility has installed 8 Koppers Electrostatic Precipitators since 1947

YEARS of cost-saving, highly efficient performance preceded this latest installation of Koppers Electrostatic Precipitators. During these years, this leading Eastern public utility was able to judge Koppers by on-the-job operation—the most positive proof of performance.

Proves Performance on the Job

Ten years ago, this company purchased its first two Koppers Electrostatic Precipitators for fly ash removal. Satisfactory performance and low maintenance costs justified the purchase of additional Koppers units that were installed in a total of 4 stations. The eight units furnish highly effective, trouble-free operation in a varying range of CFM capacities.

Supplies a Wide Range

The eight Koppers Electrostatic Precipitators serve boilers ranging in capacity from 570,000 #/hr to 950,000 #/hr. Guaranteed efficiency runs as high as 98%, depending on the need of each application. This ability to engineer for a wide range of capacities enables Koppers to satisfy the needs of each station.

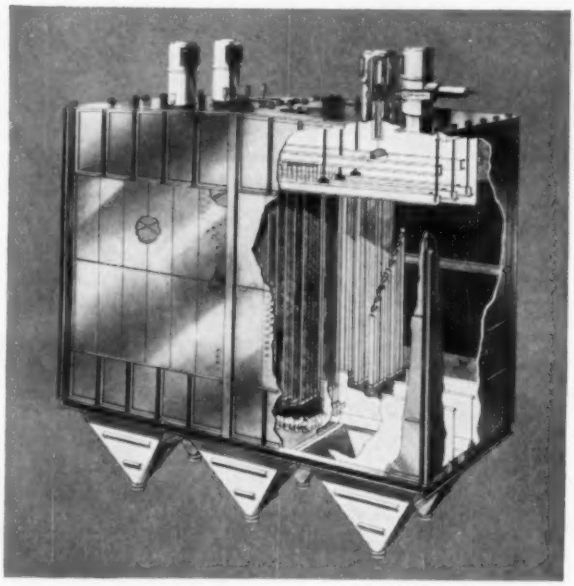
Meets Individual Plant Needs

Koppers custom-designs each Electrostatic Precipitator. Koppers units remove boiler fly ash before the flue gas is discharged from the stack. In designing Electrostatic Precipitators, Koppers utilizes its knowledge of the characteristics of various coals, types of boilers and methods of firing.

Backed by Know-How

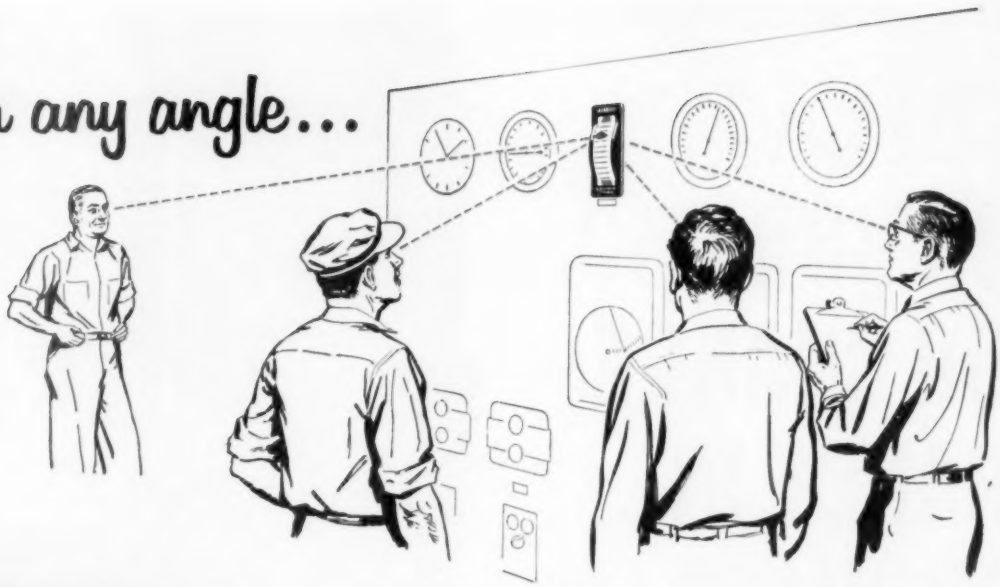
Koppers gas cleaning experience goes back 75 years. This experience is backed up by extensive research facilities at Verona, Pa., and Baltimore, Md. From this experience and research has come gas cleaning equipment for all sizes and types of plants.

Get the most out of your gas cleaning dollar. Write KOPPERS COMPANY, INC., Metal Products Division, Industrial Gas Cleaning Dept., 4401 Scott Street, Baltimore 3, Maryland.



This cutaway photo of a Koppers Electrostatic Precipitator shows shell, vibrators, and collecting and discharge electrodes. The actual design and arrangement of elements vary widely because Koppers Electrostatic Precipitators are custom-engineered to fit the requirements of each installation.

from any angle...



BOILER WATER LEVELS ARE EASIER TO READ with YARWAY INDICATORS

No matter where you stand, you can see at a glance your boiler water level in the Yarway Remote Liquid Level Indicator. The clear, "wide vision" face permits easy readings from any point in a 180° arc.

Readings are instant and accurate because the operating mechanism is actuated by the boiler water itself—by the pressure differential between a constant head and the varying head of water in the boiler drum. Pointer mechanism is never under pressure.

Yarway Remote Indicators are available fully compensated for every change in boiler temperature and pressure and they can be connected to Electronic Secondary Indicators or remote Hi-Lo Alarm Signals (lights or horns), located at any other point in the plant. Also available, Yarway Recorders working on same simple principle.

Over 12,000 Yarway Remote Indicators already installed.

Write for full details on Yarway Indicators for boilers, heaters and other applications. Bulletin WG-1824 tells all, shows typical hook-ups.

YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

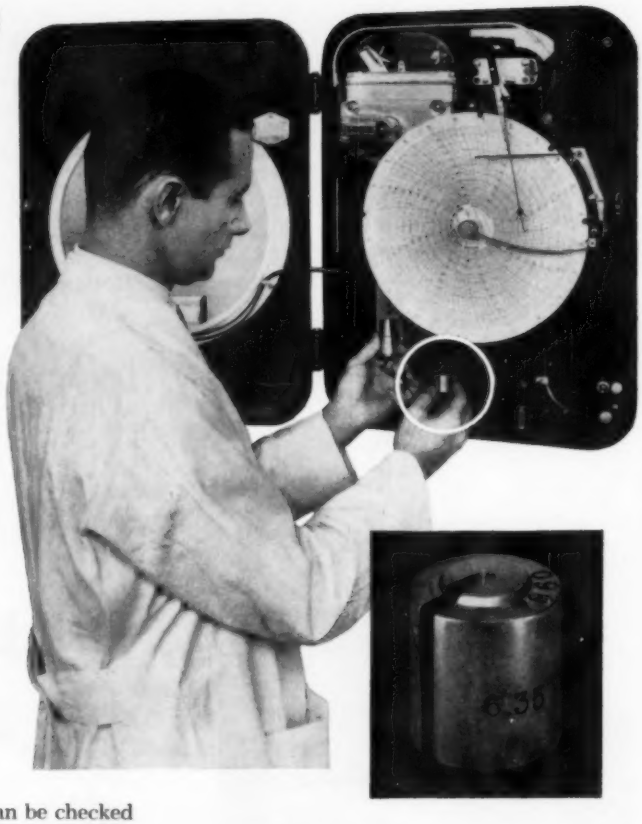
YARWAY

...a good way to specify remote liquid level indicators

HAGAN RING BALANCE FEATURES—NO. 3

CHECK CALIBRATION OR CHANGE RANGE IN MINUTES

without water columns—without disconnecting meter from line



TIME SAVER—This shows how easily a Ring Balance can be checked. Note there are no two-story water columns—one man is doing the job—and the meter has not been disconnected from the line. In fact, Ring Balance can be checked at full static pressure if desirable.

The check weight is factory calibrated against a micrometer type manometer, and its equivalent in inches of water column is stamped on the side. The serial number of the meter to which it belongs is also stamped on the collar. A full set of calibrated weights is supplied with each meter.

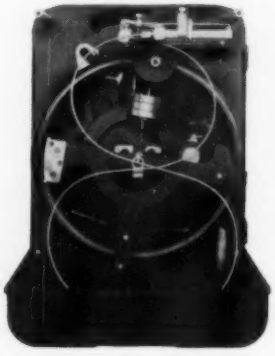
The calibration of any Hagan Ring Balance meter can be checked—in minutes—by simply hanging the appropriate weight on the check weight rod. Similarly, range change over a seven to one differential range can be done with equal speed and accuracy.

In terms of instrument technician's time, you can easily figure how much this one feature of the Ring Balance will save you. And, you don't have to take a busy pipefitter away from other work to break connections.

Ask your Hagan engineer to show you how easily range change and calibration checks can be made, using only the set of check weights supplied with each meter. Ask him, too, to explain some of these other outstanding features of the Hagan Ring Balance:

1. High sensitivity at low flows due to unique range calibration system. Full scale deflection at ½" WC.
2. Safe operation with rings rated at 2,500, 6,000, 15,000 psig. No gaskets, no stuffing boxes.
3. Sealing fluid density and level not critical. No eye-droppers.
4. Interchangeable ring assemblies for full scale ranges from 0.5" WC to 560" WC. Adjustment on any one ring over a seven to one differential range.
5. Wide range computation and/or compensation by means of built-in, easily checked mechanisms available on most models.
6. Pneumatic or electric transmission also available.

Bulletin MSP-141 describes these features and the new design of the Hagan Ring Balance meter case. ASK US FOR IT.



Rear view of Ring Balance with cover plates removed. Here the test weights are in position on the test weight rod. Note accessibility of all parts for easy adjustment.

HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY, HALL LABORATORIES
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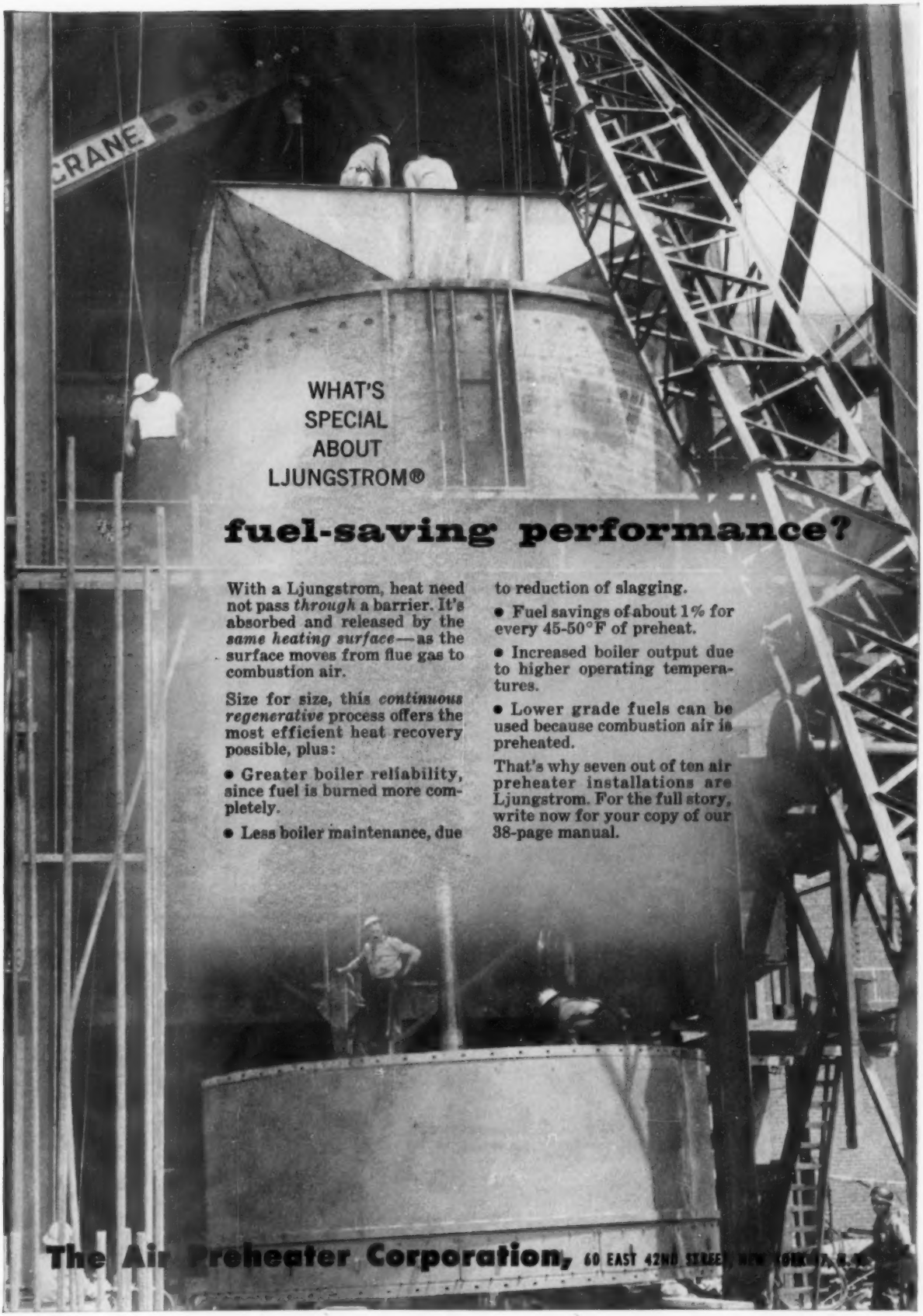
OFFICES IN: MONTREAL, TORONTO, VANCOUVER, EDMONTON



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SPECIAL
ABOUT
LJUNGSTROM®

fuel-saving performance?

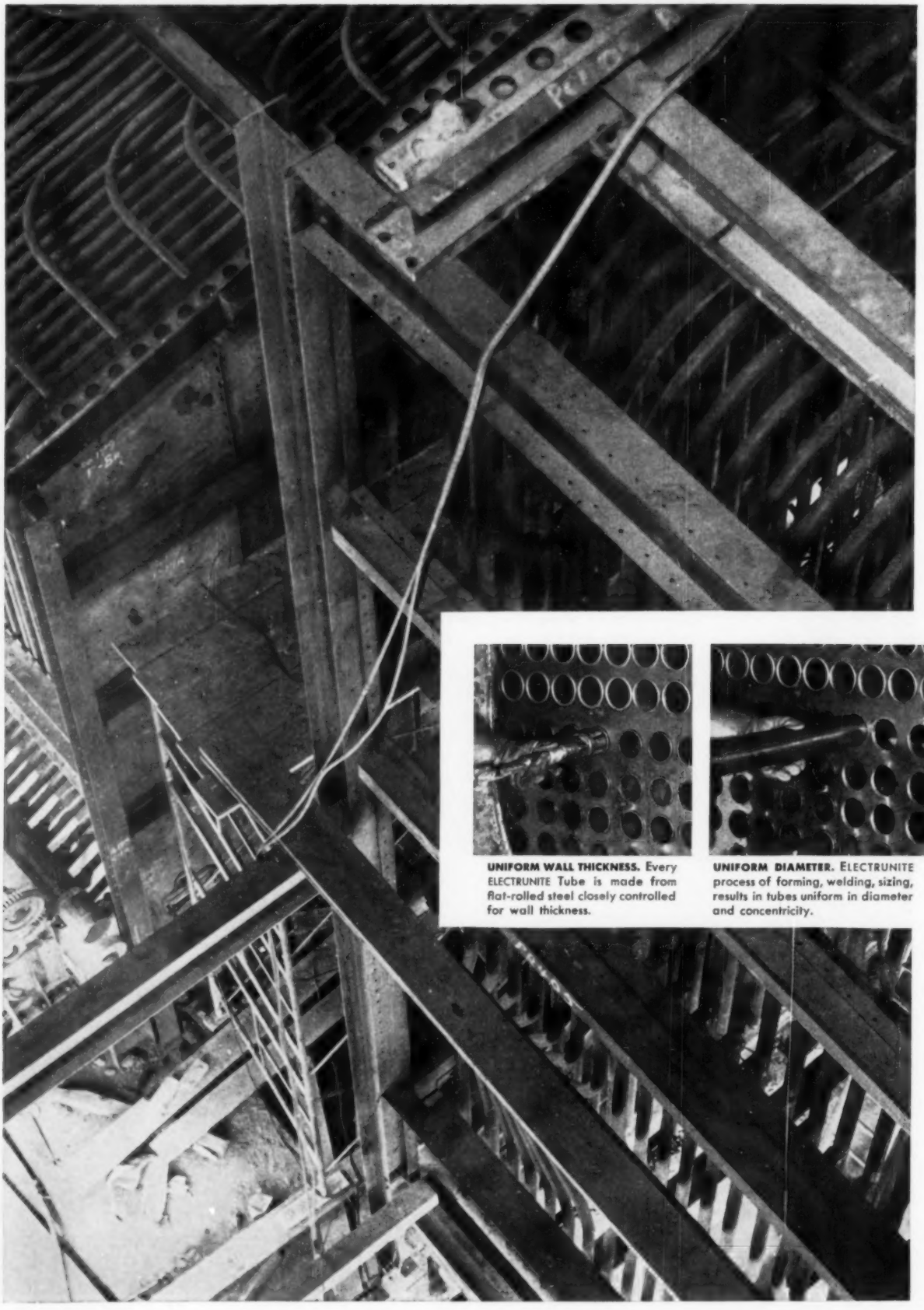
With a Ljungstrom, heat need not pass *through* a barrier. It's absorbed and released by the *same heating surface*—as the surface moves from flue gas to combustion air.

Size for size, this *continuous regenerative* process offers the most efficient heat recovery possible, plus:

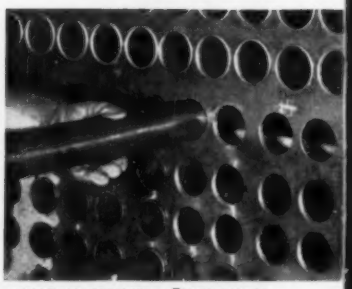
- Greater boiler reliability, since fuel is burned more completely.
- Less boiler maintenance, due to reduction of slagging.
- Fuel savings of about 1% for every 45-50°F of preheat.
- Increased boiler output due to higher operating temperatures.
- Lower grade fuels can be used because combustion air is preheated.

That's why seven out of ten air preheater installations are Ljungstrom. For the full story, write now for your copy of our 38-page manual.

The Air Preheater Corporation, 60 EAST 42ND STREET, NEW YORK 17, N. Y.



UNIFORM WALL THICKNESS. Every ELECTRUNITE Tube is made from flat-rolled steel closely controlled for wall thickness.



UNIFORM DIAMETER. ELECTRUNITE process of forming, welding, sizing, results in tubes uniform in diameter and concentricity.

Bird's-Eye View of Uniformity...

Republic ELECTRUNITE Boiler Tubing

Installed at LeTourneau-Westinghouse Plant

Power, key to productivity, demands a power plant designed and engineered to meet critical requirements and severe operating conditions of service. That is why Republic ELECTRUNITE® Boiler Tubes were specified for the new LeTourneau-Westinghouse Company installation at Peoria, Illinois.

This new power plant, furnished by the Erie City Iron Works Company, Erie, Pennsylvania, has a designed capacity of 40,000 pounds of steam per hour and operates at 125 psi.

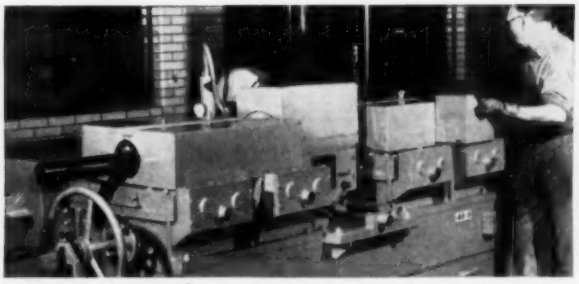
Each length of Republic ELECTRUNITE Boiler Tubing is hydrostatically or electronically tested to conform with the applicable ASTM specification and the ASME Boiler and Pressure Vessel Code, as well as local, state and boiler-insurance requirements. And stress values for Republic ELECTRUNITE tubes are the same as those for tubes made by other processes for temperatures up to 850°F. ELECTRUNITE is available for pressures over 2000 psi. in various sizes and wall thicknesses.

Made of highest quality flat-rolled open-hearth steel produced in Republic's own mills, carefully controlled every step of the way, are reasons why more and more Republic ELECTRUNITE is specified by designers, engineers, and operators for vital steam generating units operating in every industry and community field.

For additional Republic ELECTRUNITE Boiler, Condenser, or Heat Exchanger Tubing facts, call your Republic representative or send coupon today.

UNIFORM STRENGTH. Tests prove ELECTRUNITE process results in a tube with a weld as strong or stronger than the base metal.

UNIFORM DUCTILITY. Full normalizing, plus characteristics of Uniform Wall Thickness and Diameter, assures easy workability.



SPECIFY FARROWTEST® — the most conclusive, nondestructive electronic tubing test in use today. Developed by Republic, FARROWTEST provides detector coils that can electronically spot irregularities in tube walls which would be hidden from routine test procedures. Send for brochure today.

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KALAMAZOO, MICHIGAN TEL. FIreside 3-2581

September 30, 1957

Mr. O. A. Soderberg
District Manager
Combustion Engineering, Inc.
1537 Book Building
Detroit 26, Michigan

Dear Al:

Nineteen months ago we placed boiler No. 9 in service. Since No. 9 is a C-E boiler, we thought you might be interested in the following information.

The paper industry is highly competitive and a difference of a fraction of a cent per pound of paper often means the difference between selling and not selling a customer. When it is considered that 11% of the manufacturing cost of our paper is power cost, it can be seen that any reduction in power cost has a real influence on the cost of the paper produced.

The installation of No. 9 boiler has contributed to reducing power costs in several ways.

(a) INCREASED EFFICIENCY

Boiler No. 9 replaced three existing boilers having an average efficiency of 78% with one boiler having an efficiency of 87.2%.

(b) REDUCTION IN FUEL COST

The three boilers replaced required coal having an ash fusion temperature above 2500 degrees F., whereas in No. 9 furnace we have burned, with no difficulty, coal having an ash fusion of 2100 degrees F. The ability of the boiler to use such coals opens up sources of coal supply hitherto unsuitable for our use, but which are now economically attractive.

(c) LOW MAINTENANCE AND HIGH AVAILABILITY

Maintenance costs to date have been very low. The boiler has been in operation nineteen months and the only outage for repairs occurred

Plants at KALAMAZOO, MICHIGAN
DEVON, PENNSYLVANIA
HOUSTON, TEXAS
STURGIS, MICHIGAN

ASSOCIATED COMPANIES of the KALAMAZOO VEGETABLE PARCHMENT COMPANY
THE KVP COMPANY LIMITED, Espanola, Ontario
APPLEFORD PAPER PRODUCTS LIMITED, Hamilton, Ontario and Montreal, Quebec

shortly after the unit was put in operation, when soot blower misalignment caused cutting of several tubes. Fortunately, this occurred at the end of the week when the boiler was taken off the line for a scheduled outage and our own maintenance crew made temporary repairs by seal welding the cuts. Shortly after, Combustion, at their own expense, replaced sections in six damaged tubes during a scheduled Sunday outage. This work required about eight hours and no production time was lost.

Each of the two pulverizers has handled over 50,000 tons of coal without maintenance other than minor adjustments.

(d) LIBERAL BOILER DESIGN

The ability of the boiler to handle sudden increases in load was demonstrated when it was called upon to pick up the load of one of the other boilers which was tripped off the line due to mechanical equipment failure. At that time No. 9 boiler output increased from 175,000 lbs. per hour to 230,000 lbs. per hour without difficulty and without interruption to manufacturing production. This load was 30% above the maximum continuous rating for which the boiler was designed. It may be of further interest to you to know that the liberal design of the boiler permits it to carry a load in excess of the above, the limiting factor being the capacity of the feed water valve.

As you may gather from the above, we are greatly pleased with this installation.

Sincerely yours

THE KVP COMPANY

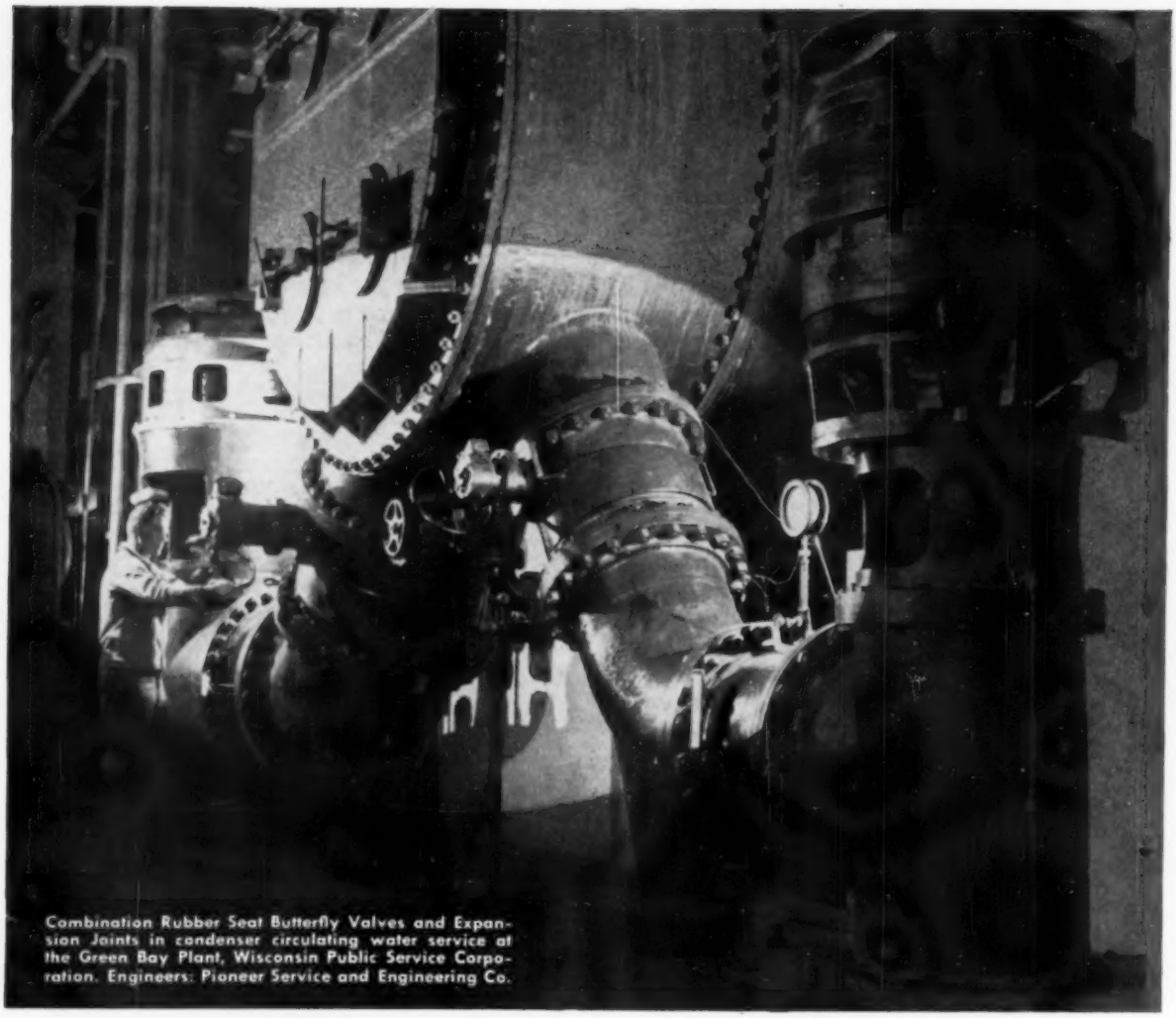
Edward A. Wade
Project Engineer

EAW:ss

COMBUSTION ENGINEERING, INC., Combustion Engineering Building, 200 Madison Avenue, New York, N. Y.

C-E
C-134

All Types of Steam Generating, Fuel Burning and Related Equipment; Nuclear Reactors; Paper Mill Equipment; Pulverizers; Flash Drying Equipment; Pressure Vessels; Soil Pipe



Combination Rubber Seat Butterfly Valves and Expansion Joints in condenser circulating water service at the Green Bay Plant, Wisconsin Public Service Corporation. Engineers: Pioneer Service and Engineering Co.

GREEN BAY...Combines Butterfly Valves with expansion joints for new economy

Drop-tight shutoff, plus provision for pipeline expansion and ease of assembly are provided here in one compact Pratt unit. By combining the Butterfly Valve with the expansion joint, space requirements are minimized and maintenance (and initial cost) of one set of flanges and bolts is eliminated. This is a typical Henry Pratt engineering job—the mechanisms are the simplest available . . . for economy and minimum maintenance, and they are carefully designed and built for peak efficiency and operating ease.

Henry Pratt pioneered the use of Rubber Seat Butterfly Valves in power plants. Combined with permanently drop-tight shutoff, the inherent simplicity and compactness of this valve permitted a new concept of large-diameter valving by power plant engineers.

Pratt Rubber Seat Butterfly Valves grew with the Power Industry for thirty years, and today are being installed in modern, nuclear power plants. For valve design—with **imagination**—see Henry Pratt.

NEW! Latest, most accurate pressure drop and flow data, conversion tables, discussion of butterfly valve theory and application plus other technical information . . . Write for Manual B-2D.

HENRY PRATT

RUBBER SEAT Butterfly Valves

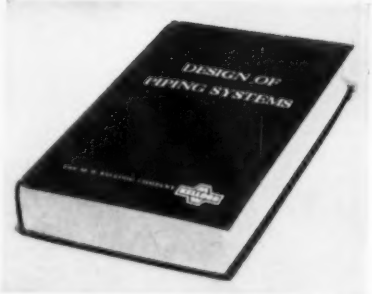
Henry Pratt Company, 2222 S. Halsted St., Chicago 8, Ill. Representatives in principal cities

KELLOGG'S ERECTION TECHNIQUES KEEP PACE

K-WELD* is one of M. W. Kellogg's many advanced shop fabrication techniques which have been adapted by the company's construction department for field erection of critical power piping. A patented inert gas-shielded method of arc welding which eliminates backing rings and oxidation, K-Weld provides in field erection a smooth internal wall contour equal to that obtained under controlled shop conditions. For "average" as well as super-critical operating conditions, wherever the ultimate in welding is required, more and more power generating companies are turning to K-Weld.

A typical example is found currently in a 137,500 KW unit for a large eastern utility plant. Here, Kellogg is erecting the critical piping for the latest unit. Reheat piping, being K-Welded above, is 2¼% chrome-1% molybdenum alloy, 24.8750" OD, 1.1875" wall thickness. Main steam line is 10.906" ID, 2.410" minimum wall thickness, and 7.906" ID, 1.792" minimum wall thickness, and will operate at 1,940 psi, 1,000 F throttle temperature. For maximum performance, K-Weld is being used on both the main steam line and hot reheat line.

M. W. Kellogg welcomes inquiries on its complete service to the power piping industry from consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.



Kellogg keeps pace in theory as well as practice. This 400-page book is the most comprehensive work ever made available publicly on the design of power piping. This volume, now in its 2nd Edition, is published by John Wiley & Sons, Inc., New York.

FABRICATED PRODUCTS DIVISION
THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.
A SUBSIDIARY OF PULLMAN INCORPORATED

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POWER PIPING—THE VITAL LINK

**Trademark of The M. W. Kellogg Company*

In Iron Body Wedge Gate Valves,
Outside Screw and Yoke Design,

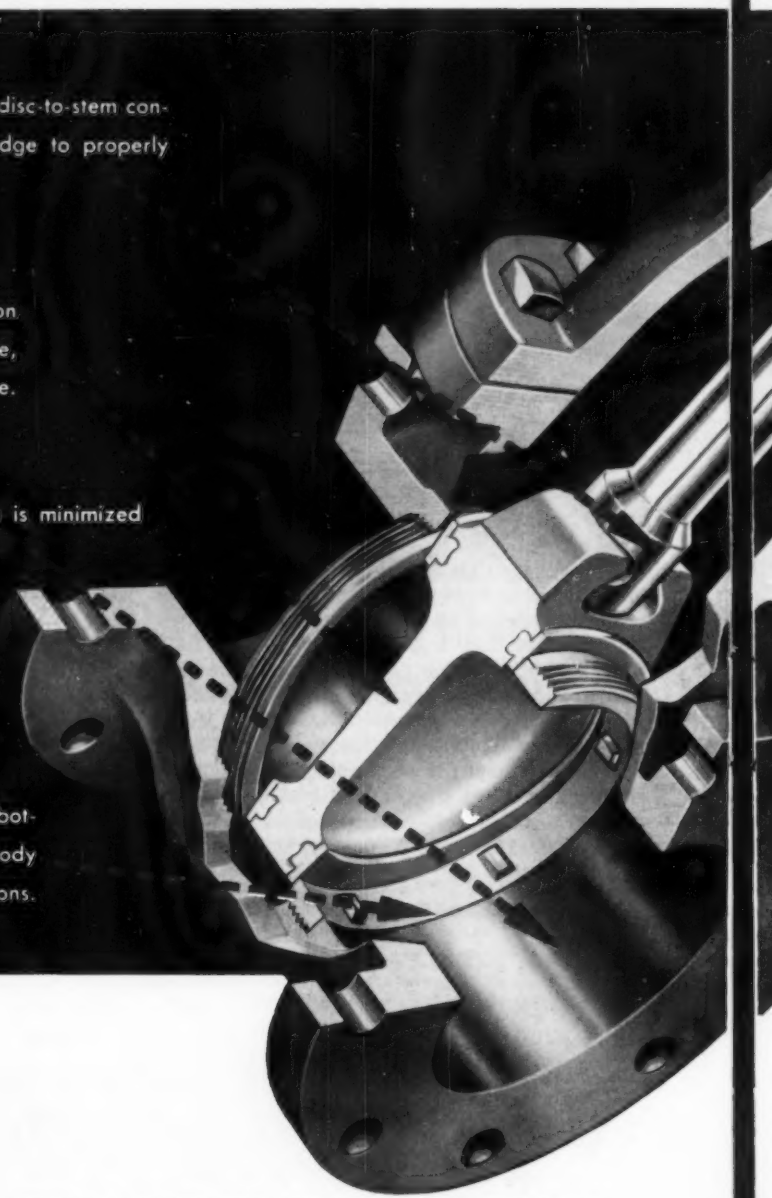
Walworth offers you these 8 outstanding advantages!

STRONGER CONNECTIONS. T-head disc-to-stem connection on OS&Y types permits wedge to properly seat itself.

TIGHTER SEAL. Solid web type disc on OS&Y valves provides tight closure, greater strength and longer service.

REDUCED TURBULENCE. Fluid action is minimized due to this straight-flow port design.

FEWER OBSTRUCTIONS. Seat rings of bottom-seated types are screwed into body to prevent gum and grit accumulations.



*WALWORTH is a registered trademark of WALWORTH COMPANY

Walworth Subsidiaries: ALLOY STEEL PRODUCTS CO. · CONOFLOW CORPORATION · GROVE VALVE AND REGULATOR CO.

SURE-GRIP HANDWHEEL. Fluted design assures a sure grip, even with greasy gloves.

HIGH CORROSION RESISTANCE. Brass liner protects glands from deterioration and scoring.

EASIER REPACKING. Hinged gland eye-bolts on OS&Y valves permit fast maintenance under full pressure.

LESS DAMAGE. Bronze back-seat bushing in bonnet of OS&Y valves prevents scoring, guides stem accurately.

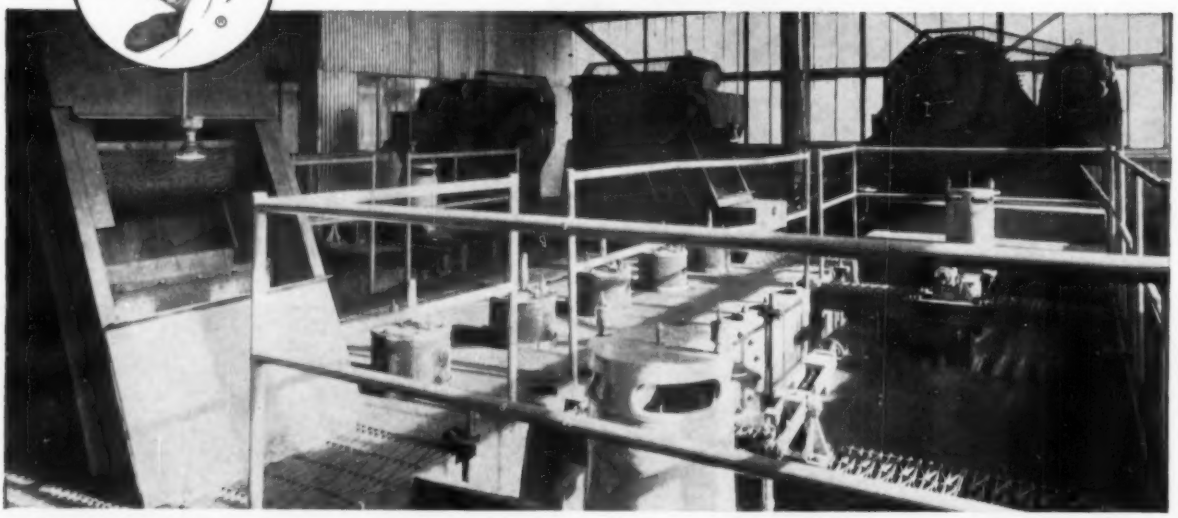
Walworth Iron Body Gate Valves are available with screwed or flanged ends, in sizes and types for every purpose. For full information see your Walworth Distributor or write: *Walworth Company, 60 East 42nd Street, New York 17, N. Y.*

WALWORTH*

DISTRIBUTORS IN PRINCIPAL CITIES THROUGHOUT THE WORLD

M&H VALVE & FITTINGS CO. • SOUTHWEST FABRICATING AND WELDING CO., INC. • WALWORTH COMPANY OF CANADA, LTD.

WHY CHESSIE'S RAILWAY IS FIRST IN COAL



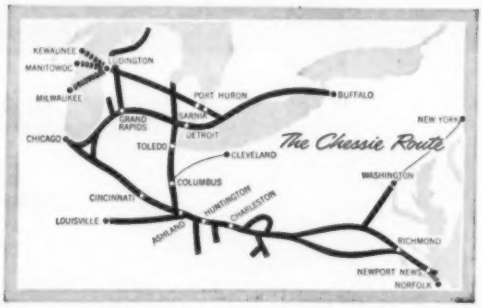
SUPERIOR COAL. The entire output of this mine is processed by automatic compound coal cleaning equipment. Producers on the Chesapeake and Ohio are prepared to supply you with highest quality coal of the type best suited to your needs and processed to your own specifications.

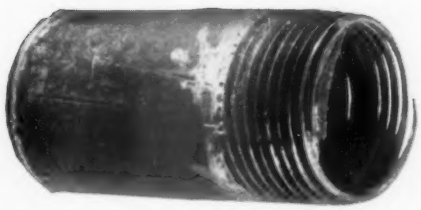
SUPERIOR SERVICE. With the world's largest fleet of coal cars, kept in better than 99% good order, Chesapeake & Ohio trains roll at top speed over a roadway specially designed and maintained for heavy coal haulage.

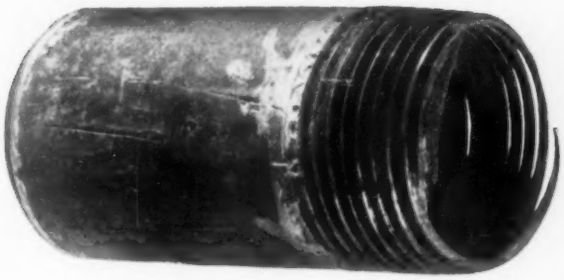
For dependable deliveries of top quality coals, contact coal producers on the C & O. And for specific help in meeting your own fuel requirements, write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake and Ohio Railway Co., Terminal Tower, Cleveland 1, Ohio.

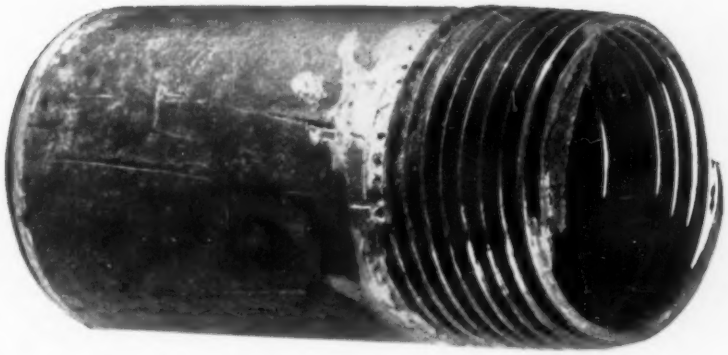
Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL









● *Unretouched photos showing carbonic acid destruction typical of untreated pipelines.*

EASY TO SEE THROUGH – AFTER IT HAPPENS

It's too late for water treatment after the damage is done. Replacement of these threadbare nipples in the return line was only a matter of time. The grooving-type corrosive action of carbonic acid took care of that.

Destruction like this can be stopped with Dearborn Alkameen,* an amine in liquid form which dissolves in the condensate to neutralize the corrosive action of carbonic acid.

A Consulting Service for You. Whatever your problems—raw water supply...power plant data...cooling towers, ponds...types of fuel...equipment...test and control methods—Dearborn has the engineers, the experience and the facilities to assist you in developing the program exactly suited to your needs. Your Dearborn representative will outline the many advantages a Dearborn Consulting Service Program will give to you.

**Alkameen is a trade-marked product of Dearborn Chemical Company.*

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MEANWHILE SEND FOR THE NEW
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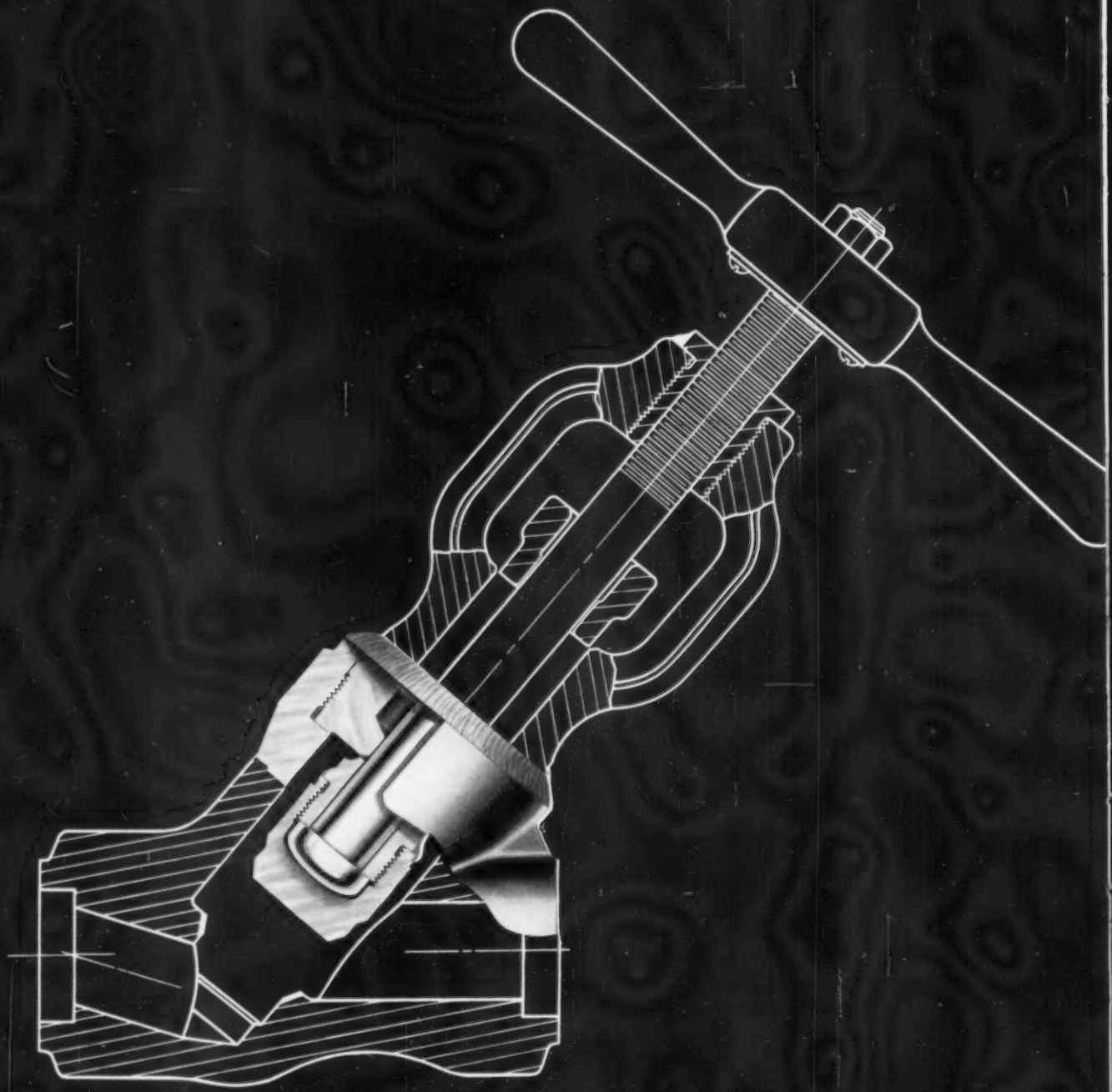
Manufacturing plants in CHICAGO • LINDEN • LOS ANGELES • TORONTO • HONOLULU • HAVANA • BUENOS AIRES



EDWARD UNIVALVE

What's New from Edward Valves, Inc.

New Products . . . Problems and Solutions. . . Information on Steel Valves from Edward, Long-Time Leader in the Field!

Shoulder, thread and weld make

Superior "Univalve" Body-Bonnet Joint

Edward valve researchers were assigned three main goals in developing the Univalve* . . . first, design a globe valve for high pressure-temperature service—that would *stay* leak-proof . . . second, eliminate—as far as possible—the necessity for maintenance . . . third, fabricate all pressure-containing parts of forged steel for maximum strength and soundness.

How well they succeeded is illustrated by this fact: in many hundreds of advanced temperature-pressure applications all over the world, Edward Univalves have given consistently superior service. The *reason* for this is simple . . . Univalves, properly maintained, simply do not leak.

WELD SEALS JOINT

In the Univalve, a bead of fine-grained weld seals the body-bonnet joint to maintain perfect pressure tightness in any service. A guiding section above the threads protects them from the seal-weld; the threaded section and body shoulder carry the pressure load and insure accurate alignment. The rugged threaded bonnet—with opening just large enough to accommodate the stem—provides a pressure-tight backseat. The radiused disk nut contacts the beveled bonnet backseating surface . . . isolates packing from line pressures and temperatures . . . stretches packing life.

While the Univalve rarely needs attention, even its tough integral Stellite seating surface *can* become scored under some conditions. To strip for inspection and possible re-lapping, the seal-weld is easily removed by machining or grinding or with carbon arc or oxy-acetylene scarfing tip. Besides simple disassembly and positive backseat advantages, Univalve's one-piece gland eliminates possible small parts loss during repacking.

IDEAL FOR BLOW-OFF SERVICE. Univalves meet ASME Code for blow-off service and are adaptable for all high pressure installations.

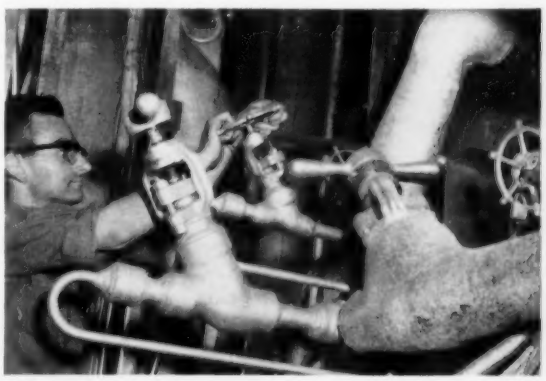
IMPORTANT UNIVALVE FEATURES:

Streamlined Flow Path reduces pressure drop, minimizes wear-producing turbulence. Univalve meets requirements for blow-off service.

Simple Packing Adjustment keeps packing maintenance down. Sturdy gland bolts, roomy yoke, one-piece forged gland.

Easy Open—Tight Close Operation of all Univalves 1¼" to 2½" made a reality with the exclusive Edward Impactor* handle.

Continuous Stellite Ring applied to body and disk, retains hardness under temperature and resists wear.



4500 LB UNIVALVE in service at Ohio Power Company's supercritical Philo station.

*T.M. Reg. U.S. Pat. Off.

EDWARD VALVES, INC.

Subsidiary of ROCKWELL MANUFACTURING COMPANY

1206 West 145th Street, East Chicago, Indiana

Edward builds a complete line of forged and cast steel valves from ⅛" to 18"; in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs; for pressures up to 7500 lbs; with pressure-seal, bolted, union or welded bonnets; with screwed, welding or flanged ends.

APEXIOR®
in today's power boilers

There's something basic about a power-field product with a job even more vital today than half a century ago — for technologically we've come a whole era since Apexior Number 1® first went to work inside boilers in 1906. The "why" of Apexior and its still-growing use in modern steam generators takes us, then, to fundamentals, best answered by asking—

WHAT IS APEXIOR?

Apexior Number 1® is a high-temperature, non-oxidizing, brush-applied coating for service on both heat-transfer and non-heat-transfer areas. Because it penetrates and becomes one with metal, Apexior seals surfaces at new, or newly cleaned, strength, isolating steel from its environment and establishing it as an independent element in steam generation.

WHY ARE BOILERS APEXIOR-COATED?

Maintaining the status quo to keep steel at peak efficiency is only the first benefit Apexior confers. The simple one-coat process actually transforms steaming surfaces. Because Apexior is smooth and deposit-repelling, metal stays cleaner longer — heat transfer is always at its highest — distribution is uniform — and circulation and evaporation proceed at top performance levels. Off the line, inspection is facilitated — cleaning, when required, is accomplished easily and quickly — and the boiler is soon back in better-than-ever steaming service.

WHERE IS APEXIOR IN USE TODAY?

Now manufactured in the United States and four foreign countries, Apexior serves the world around in electric utility central stations and plants generating power for every kind of manufacturing and service industry. Its first use half a century ago in Scotch marine boilers has been extended also over the years to floating power plants in vessels of every type and size.

CAN YOU APEXIOR-COAT ALL BOILERS?

Apexior serves under highest temperatures and pressures on any steam-or-water-contact area. It may therefore be applied to any water-tube boiler, including water walls, economizers, circulators, and reheat units — and to any fire-tube boiler where it serves on shell interiors and flue exteriors.

WHAT UNIT-SYSTEM AUXILIARIES ARE USUALLY APEXIOR-COATED?

- *Evaporators — interior surfaces, coil exteriors*
- *Deaerating heaters — shells and trays*
- *Feedwater heaters — interior surfaces*

WHAT PARTS OF STEAM TURBINES ARE APEXIOR-COATED?

- *Interior of casings and exterior of rotors, or wheels, and diaphragms.*

MAINTENANCE FOR METAL

This message is one of a continuing series. To be discussed: Apexior Number 1® in relation to . . . heat transfer, feedwater treatment, high-purity steam, standby, cleaning, cost. Watch for the answer to your question, or write

THE DAMPNEY COMPANY
HYDE PARK, BOSTON 36, MASSACHUSETTS

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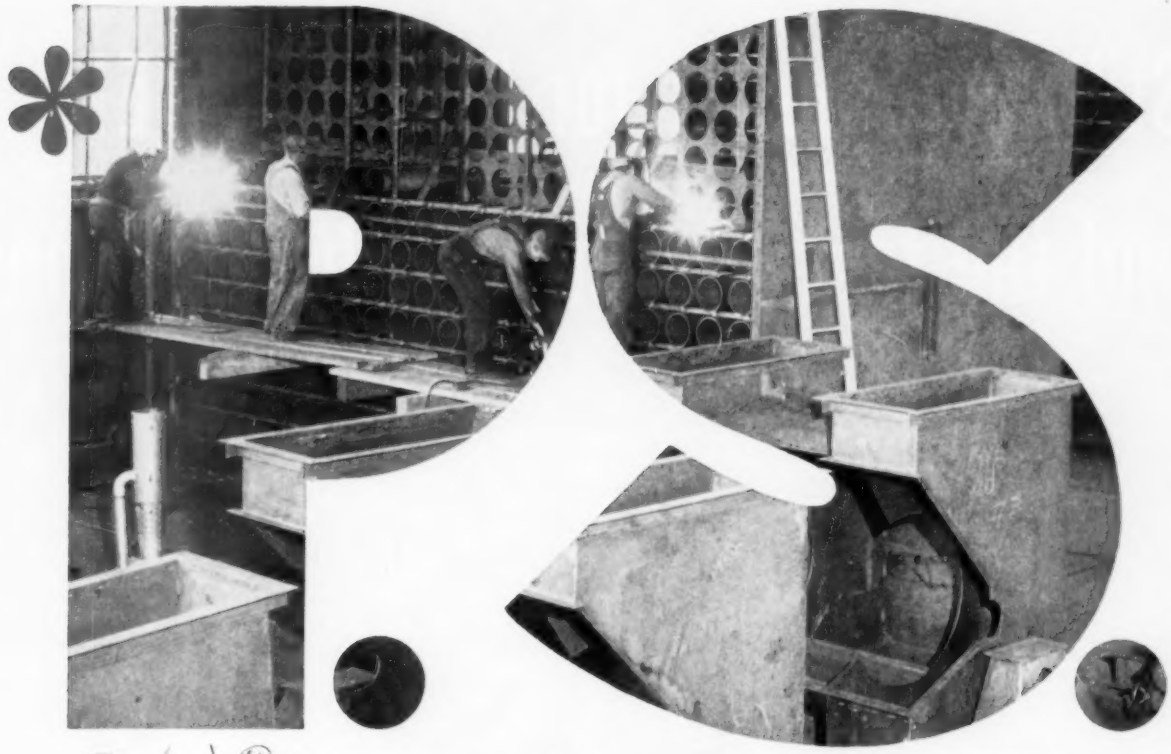


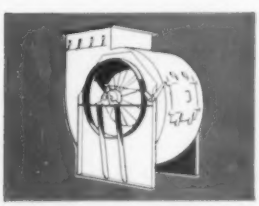
*PROBLEM SOLVERS

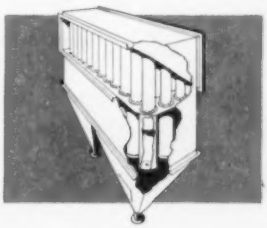
FLY ASH ARRESTOR'S research laboratory, engineering and manufacturing facilities are *totally set up* and especially experienced to provide a "dollar-saving" solution to the most perplexing dust collecting problem. Tell us about your conditions . . . what you want done!

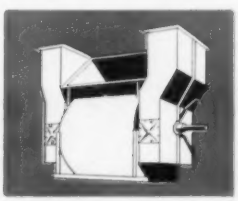
WHIRLEX *dust collecting efficiency begins with "tailored" planning.* Each dust collecting problem . . . whether nuisance elimination or process material recovery . . . gets special study and handling. FLY ASH ARRESTOR engineering solves each problem with a completely integrated, *shop-assembled* WHIRLEX Dust Collector Unit specifically designed and constructed for the job.

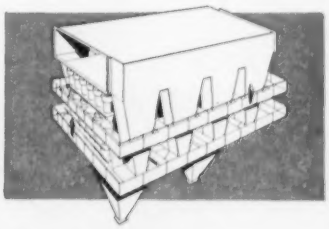
WHIRLEX *heavy-duty* industrial exhaust fans are available to handle any air moving problem. WHIRLEX *standard* forced and induced draft fans are available for boiler applications.

WHIRLEX equipment assures maximum efficiency right from the start . . . and continues to pay off with consistently low operating and maintenance costs.









FLY ASH WHIRLEX ARRESTOR

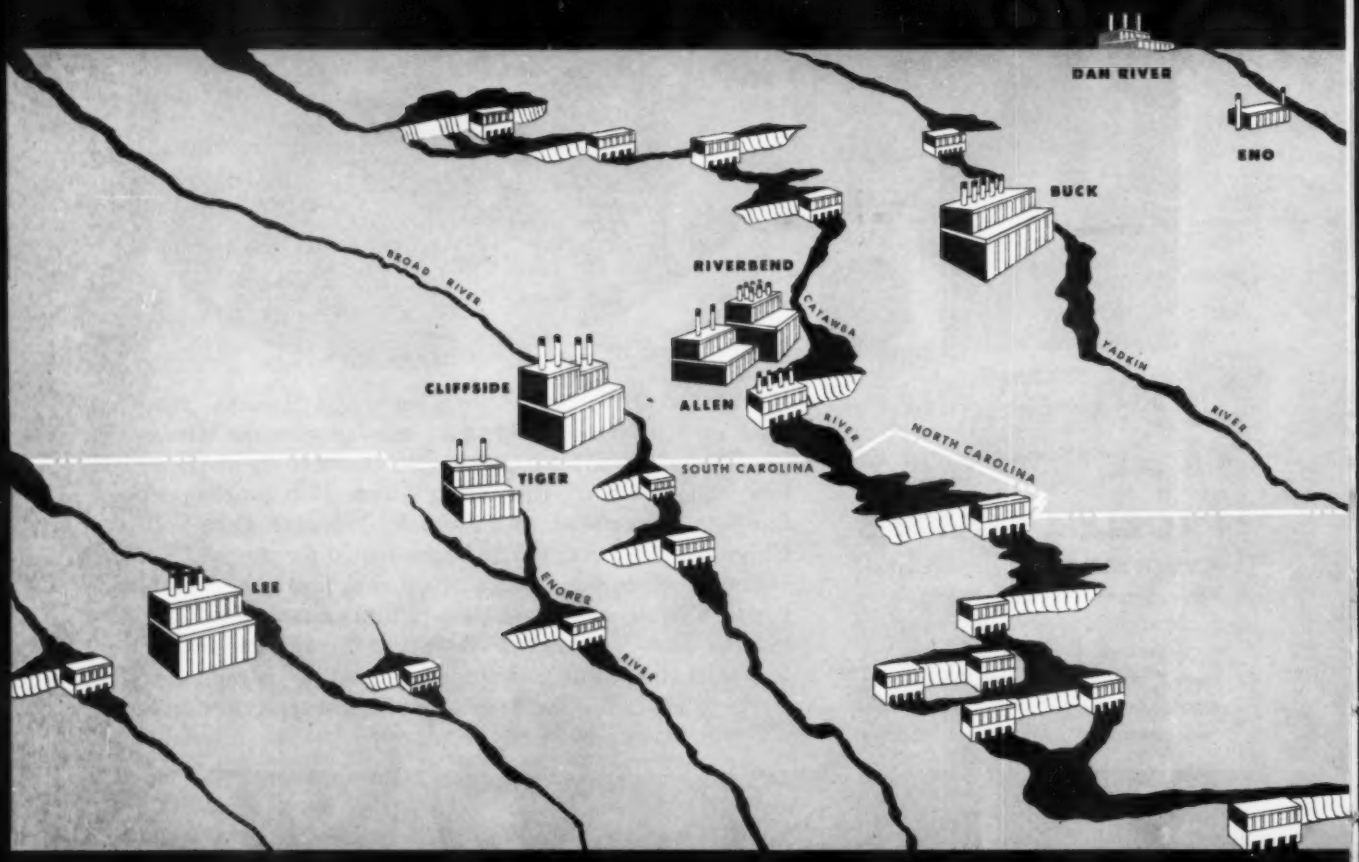
- CTF Mechanical Gas Centrifuge Collectors • MTSA 9CYT Multiple Cyclone Collectors
- Induced Draft Fans • Forced Draft Fans • Special Duct Work
- Self-Supporting Stacks • Support Structures

Write today for complete engineering data . . .

THE FLY ASH ARRESTOR CORPORATION

269 North First Street **Birmingham, Alabama**

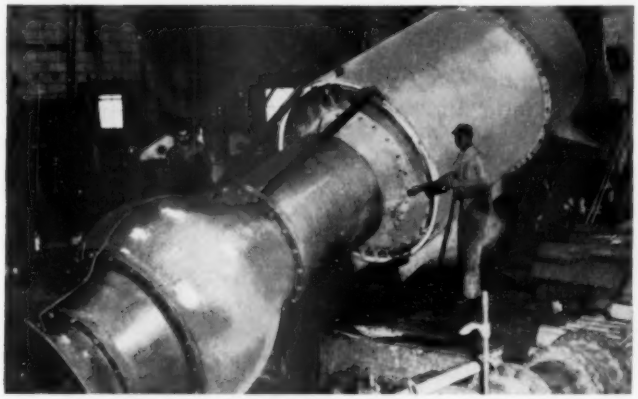
Still more power for DUKE POWER...
and the fast-growing Southern economy



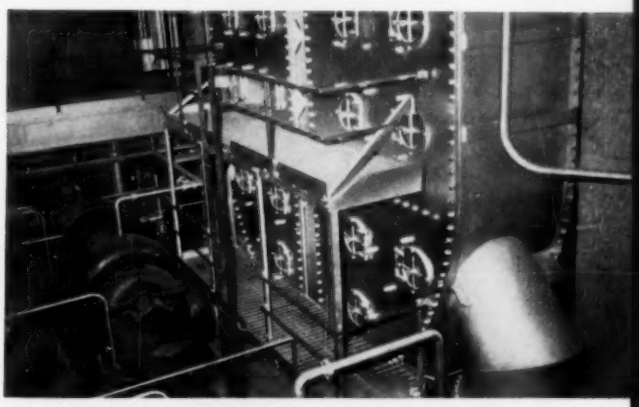
1,844,300 sq. ft. of C. H. Wheeler Surface Condensers are in use now or on order in the Duke Power System:

Station	No. of Condensers	Total Sq. Ft. Condensing Surface
ALLEN	4	530,000
BUCK	5	246,300
CLIFFSIDE	4	163,000
DAN RIVER	3	195,000
LEE	3	240,000
RIVERBEND	7	470,000
	26	1,844,300

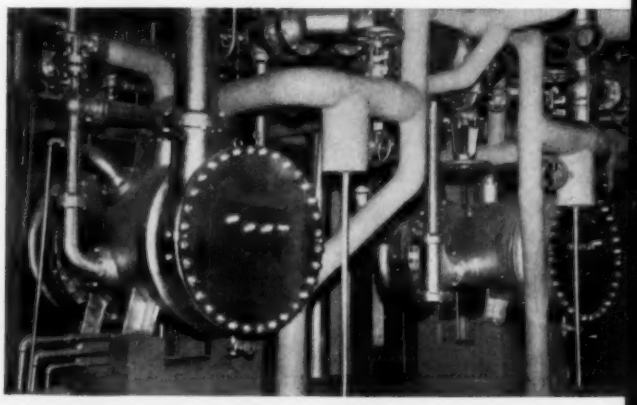
It's one of the south's greatest private power expansion programs—and C.H. Wheeler of Philadelphia is playing a leading part in it. To date, Wheeler has installed or is building 26 Dual Bank Surface Condensers, 5 Low Level Jet Condensers and a vast quantity of other power plant equipment. On the left is the story in tabular and geographic form; on this page are typical installation photographs of Wheeler equipment at Duke.



50-TON CIRCULATOR is one of 2 such pumps at Allen Plant Unit No. 1. It's a 48" x 54" Pull-Out Type Vertical Mixed Flow Pump. Capacity is 46,000 gpm. Two more of these pumps are being installed at Allen Plant Unit No. 2. The Allen Plant is the first plant in the Duke Power System to use vertical condensate pumps and circulating water pumps made by Wheeler.



AT DUKE POWER'S BUCK STATION are two C.H. Wheeler Dual Bank Surface Condensers with 75,000 sq. ft. of cooling area each. Wheeler Circulating Water Pumps are also in service at this Spencer, North Carolina Station. Other Surface Condensers at the Buck Station range in condensing area from 5000 sq. ft. (a house turbine unit) to 60,000 sq. ft.



C.H. WHEELER'S TWO-STAGE TUBEJET® Air Ejector (above) shown at Duke Power's Buck Station. These same type units have been used successfully at other power generating plants for over 30 years, with only routine maintenance. First cost and installation cost are low, installation is fast and operation simple.

ONE OF TWO 7-STAGE SPLIT CYCLE 18" x 10" Vertical Condensate Pumps (left) for Duke Power's Allen Plant Unit No. 1 ready for test. Each unit is rated at 2000 gpm against a 620-ft. total dynamic head at 880 rpm. The first three stages operate as a unit at 225-ft. head; the other four stages of each Condensate Pump operate as a booster pump at head of 395 ft.

C. H. Wheeler Mfg. Co.

19TH & LEHIGH AVENUE Philadelphia 32, Pennsylvania

Steam Condensers

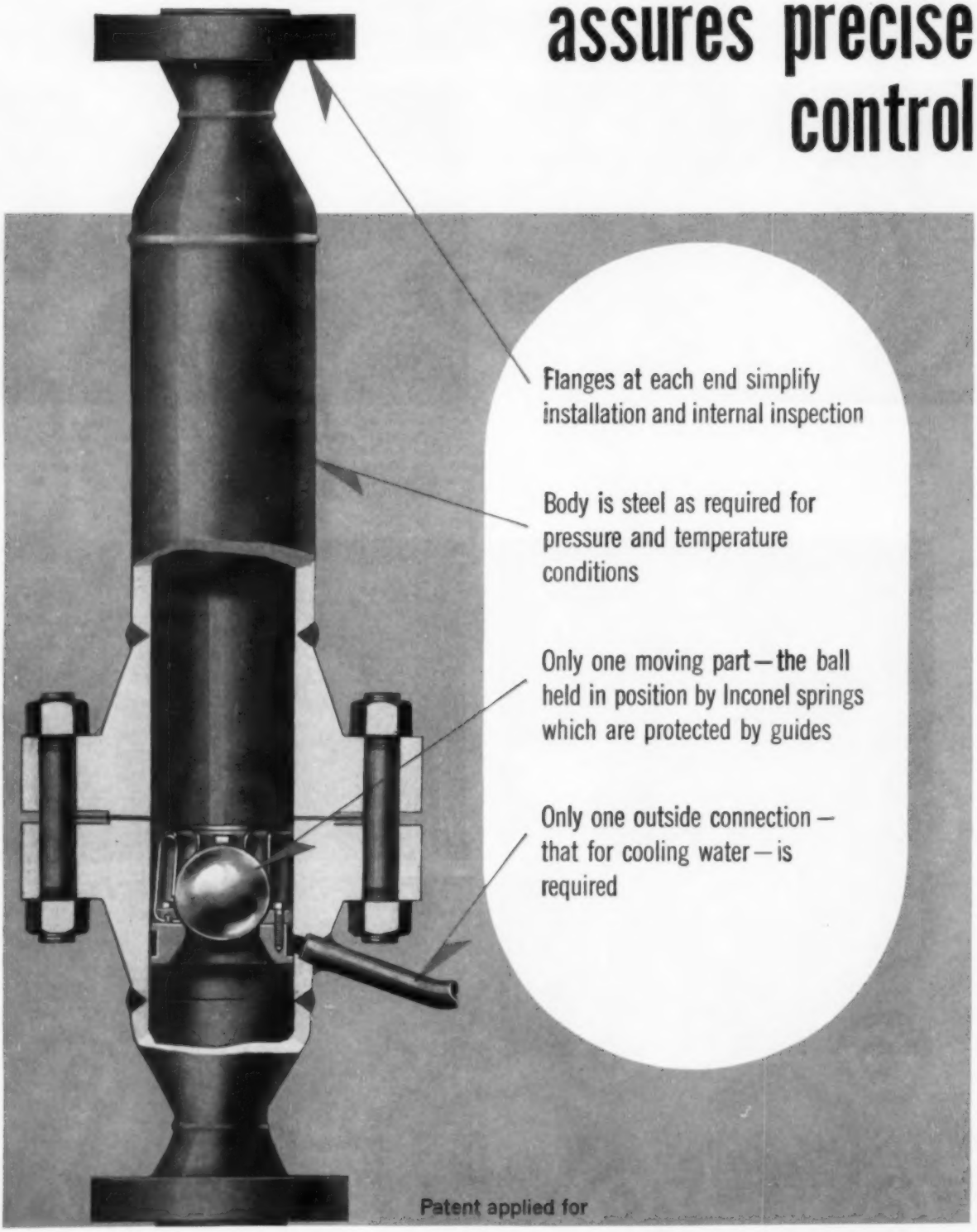
Vacuum Equipment

Centrifugal, Axial & Mixed Flow Pumps

Marine Auxiliary Machinery

Nuclear Products

New—Copes-Vulcan Variable-Orifice assures precise control


Flanges at each end simplify installation and internal inspection
Body is steel as required for pressure and temperature conditions
Only one moving part—the ball held in position by Inconel springs which are protected by guides
Only one outside connection—that for cooling water—is required
Patent applied for

Desuperheater temperature

Here is a unique desuperheating approach for close control of reduced steam temperatures, regardless of load variations. Using a weighted steel ball for controlling the orifice opening, this new Copes-Vulcan Variable-Orifice Desuperheater speeds the intimate mixing of cooling water and steam. Vaporization is so complete that reduced steam temperature can be held constant only 20 feet downstream from the desuperheater outlet — even over a 50-to-1 load range.

Advance design means:

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Incoming steam lifts the ball an amount determined by the weight of the ball and the amount of steam flow. This assures a constant pressure drop of approximately 3 psig at all rates of flow, making possible precise control over extreme load ranges. Cooling water is controlled by a Copes-Vulcan valve responsive to the temperature controller.

The Variable-Orifice Desuperheater is one of a complete line — each type engineered to meet particular operating conditions. Copes-Vulcan designs each station to meet your individual requirements.

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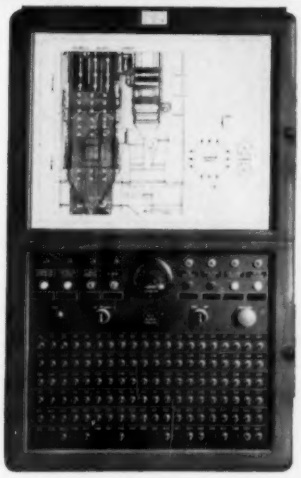
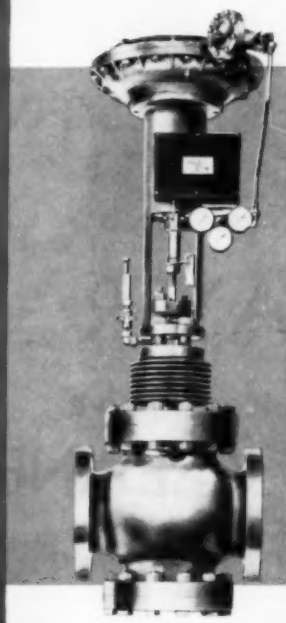
C-V NEWS NOTES



On order for a 5000-psig boiler in an Eastern utility station, this Vulcan Selective-Sequence Model SSC-120 control panel can preset four different or identical sequences of up to 120 soot blowers. 60-station Model SSC-60 control also available.



New Copes-Vulcan diaphragm-operated Type CV-D valve provides control service for applications calling for superior accuracy and dependability. Reverse or direct-acting. Sizes up to 14-inch at unlimited pressures. Write for Bulletin 1027.

New bulletin on Variable-Orifice Desuperheater gives complete description with specifications. Schematic drawings in color show typical installation and explain operating principle. For details, write for Bulletin 1037.

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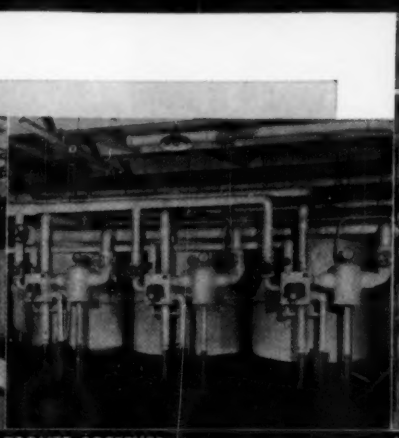

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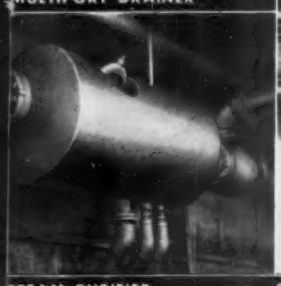

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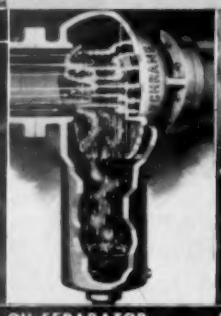

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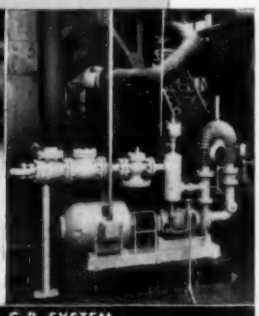

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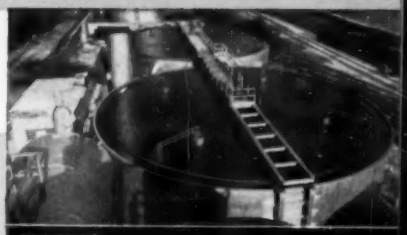
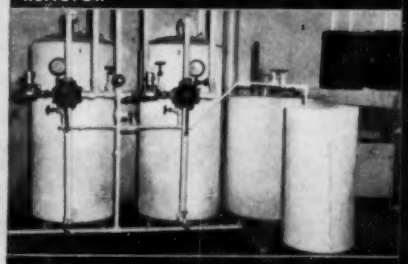
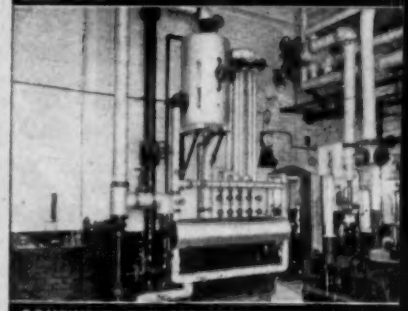


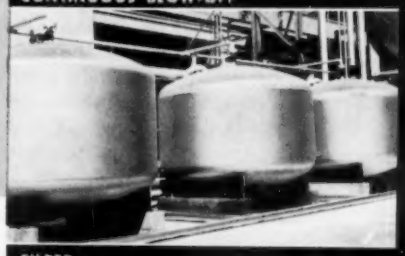
REACTOR



SALT SPLITTER



CONTINUOUS BLOW-OFF



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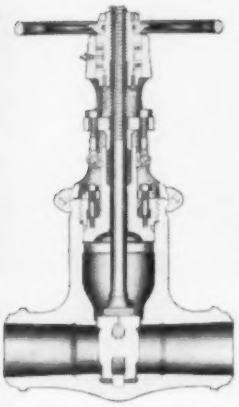

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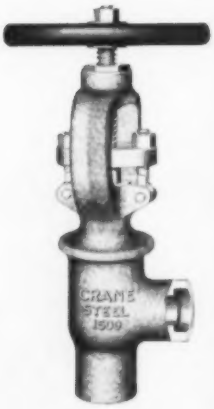

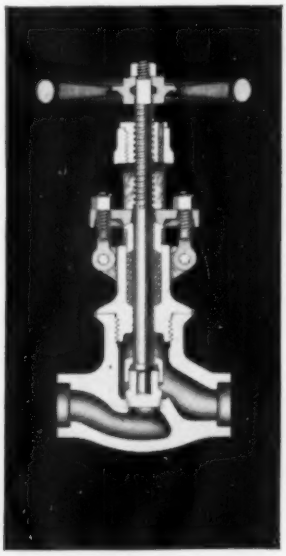

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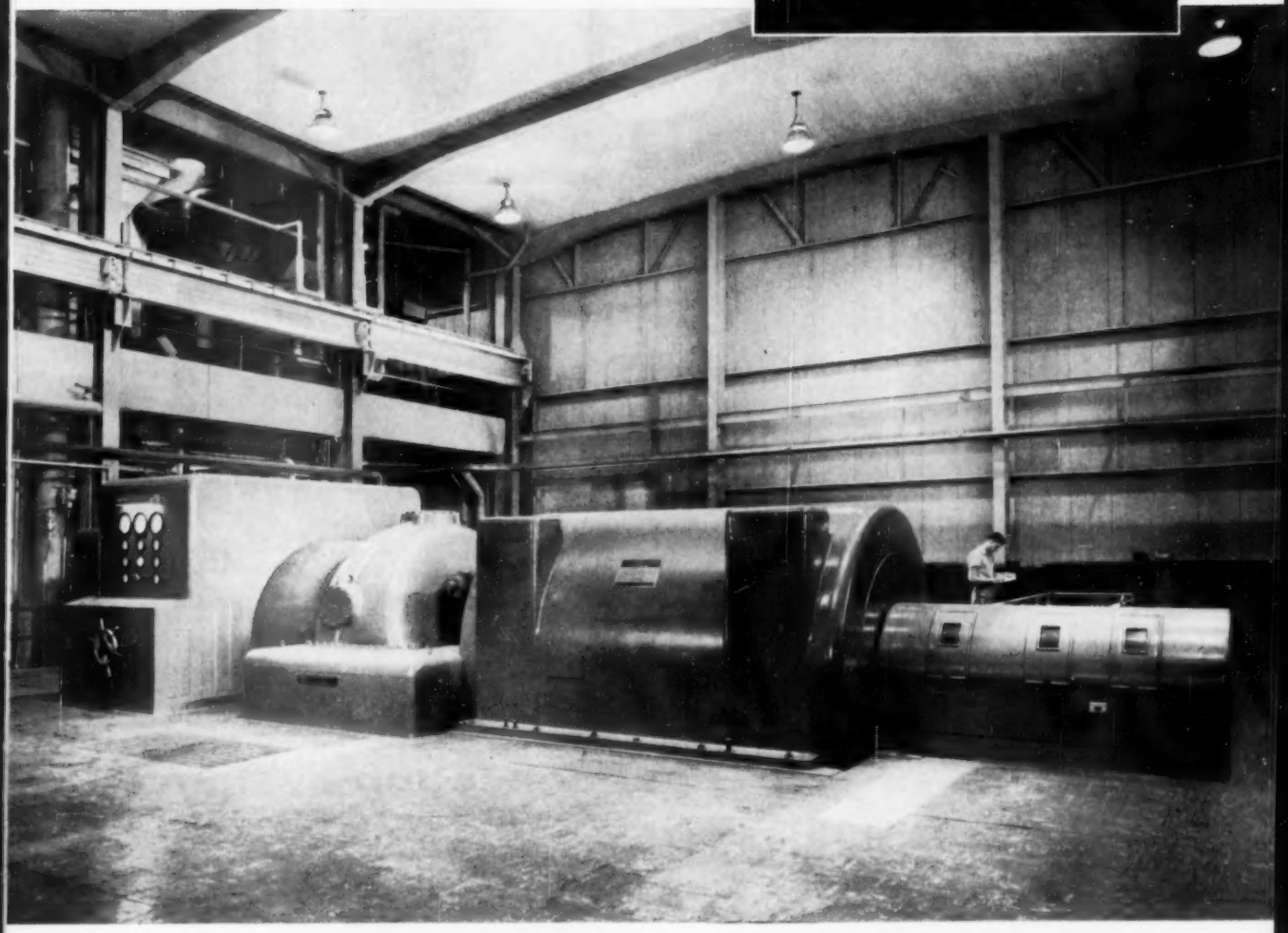

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Editorial

Solid Accomplishments at Shippingport

News stories of recent weeks have successively revealed that America's first full-scale nuclear power plant had reached criticality, generated its initial electric power, and on Dec. 23, 1957, produced its full capability of 60,000 kw. In pre-Calder Hall and pre-Sputnik days this news would have made world-wide front-page headlines. As it was it did make the front page in many newpapers in the United States, but it was far overshadowed by the flood of articles and commentaries dealing with American loss of technical leadership and the necessity for revamping educational methods in this country to improve the quality and increase the quantity of scientists and engineers.

Great as these needs for overhauling education may be, let us not lose sight of our accomplishments. In 1953 Westinghouse Electric Corp. was assigned responsibility by the U. S. Atomic Energy Commission for the design and development of a pressurized light water reactor and primary coolant circuit intended as the heat source for generating civilian electric power. On Mar. 14, 1954, the AEC accepted the offer of the Duquesne Light Company to furnish a site and certain facilities for an electric generating plant. Nearly a month latter, on Apr. 12, 1954, the Commission announced that the plant would be built near the little town of Shippingport, Penna., about 30 miles down the Ohio River from Pittsburgh. Ground was broken for the pioneering facility on Sept. 6, 1954 by President Eisenhower by remote control from Denver.

Speaking before the Atomic Industrial Forum at a meeting held in Washington, D. C., on May 24, 1954, Charles H. Weaver, now vice president of Westinghouse, made the following comments:

"We believe in the wisdom of building a full-scale pressurized water reactor. We believe that the design minimum of 60,000 kw is a sensible specification for the first plant, taking into account cost factors and the existing state of technology. . . . Likewise, we are glad that PWR is an all-civilian reactor, since this permits exploration of the pressurized water approach to industrial power without confusion or dilution either of the objective or the end results."

Shippingport is a symbol of engineering accomplishments and better things to come. No matter what the ultimate outcome of the competitive races for energy sources, Shippingport will stand as a monument to the peaceful use of atomic energy. Credit is due the many nameless individuals who have supplied the ingenuity, craftsmanship, scientific knowledge and financing that have made America's first full-scale nuclear power plant a reality and a going concern.

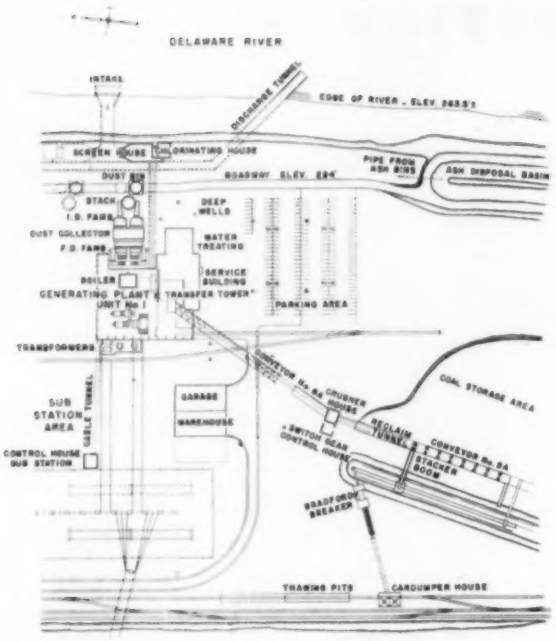

Fig. 1—Plot plan shows major plant components, location of coal handling equipment, position of boilers, turbines, Delaware River

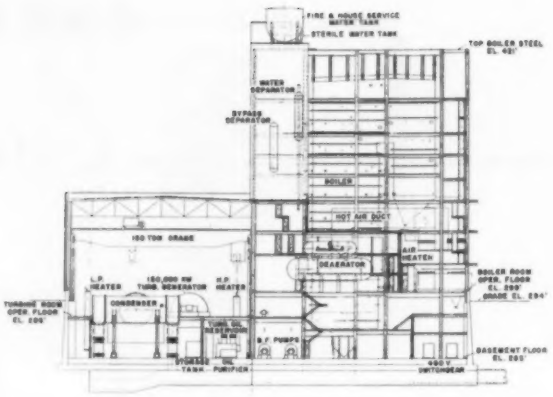

Fig. 2—Significance of the specially chosen turbine-condenser arrangement appears in the turbine foundation height of but 21 ft. Note turbine floor level is 13 ft below boiler room and 8 ft below grade elevation

A subcritical-pressure Monotube steam generator, a close-coupled, axial-flow exhaust turbine teamed with a side-entry condenser and the most recent direct energy-balance combustion control system combine in the now building Portland Station of the Metropolitan Edison Co. to mark this plant as a significant milestone in steam cycle development.

Portland Station Features Combination

THE history of power-station design in the United States is a record of continuous improvement in overall efficiency in both production and maintenance and an ever-increasing use of automation in operation. Each step in this development has been justified by an economic yardstick, which in all honesty it must be admitted has had a reasonable variation in length, often adjustable to suit the philosophy of the building organization. The competitive desire and ability of many organizations to make contributions to the advancement in power-station design is a healthy condition, and the result is evident in almost every new station built. Credit must be given to the major manufacturers of power-station equipment for their response to this desire by building equipment with distinctive features of improved design that have advanced steam cycle development.

Portland Station

Portland Station is no exception, and a primary interest in the design was to utilize as high an initial steam condition as could be justified for the size of the unit and still step forward as much as seemed reasonable in new equipment design and plant arrangement.

Specifically Portland is unique in the combination of three features; subcritical-pressure Monotube steam generator, close-coupled cross-compound axial-flow exhaust turbine and side-entry condenser, and, lastly, direct energy-balance combustion control. Other distinguishing but less significant features are (a) welded condenser tubes, (b) all-welded high-pressure heaters, (c) small bunkers and automatic coal-handling system with active outdoor storage, (d) floating high-pressure deaerating heater, (e) high-speed boiler feed pumps, and (f) two-level pressure operation.

Portland is a new station in the Metropolitan Edison Co. system located on the Delaware River near Portland, Pa., and approximately 5 miles downstream from Delaware Water Gap. Circulating water is available to support at least 1000 mw and the plant is designed for ultimate of at least six units. The capacity of the first unit will be approximately 165 mw allowing for 10 per cent overload above the manufacturer's maximum rated capacity of 150 mw. The plant arrangement is sufficiently flexible to accommodate larger units as system growth may warrant with the steam generator on the side next to the river and turbine-generator and substation away from the river. The station will be expanded in the upstream direction. The intake tunnel at the river's edge is being built initially for two units, but only the screen house for unit No. 1 is now provided. This arrangement of intake was developed to meet the requirements set up for the river-channel cross-section. In the original design the screen house was located at the river's edge and the intake was to be for one unit only, but this arrangement proved to be unacceptable to State authorities. The highest water level at this point during the August 1955 flood was approximately 292 ft elevation. The grade around the station will be elevation 294 ft and the station flood-protected to elevation 298 ft.

The station is basically a semi-outdoor design with the

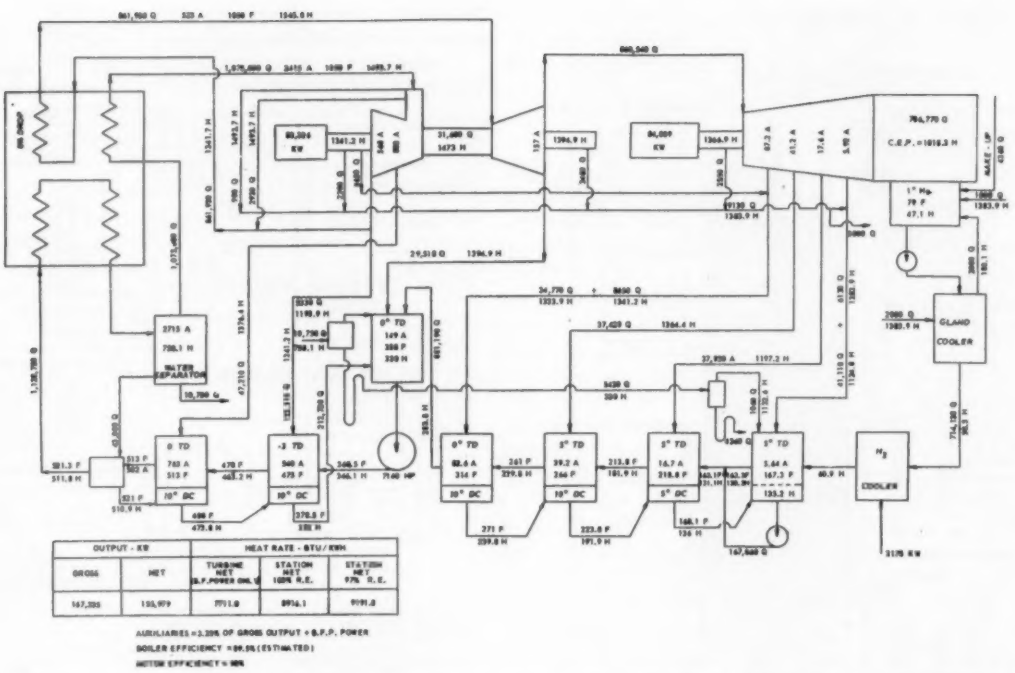

Fig. 3—Cycle heat balance, above, is a conventional one except for two water-return heat exchangers. There is a drain cooler above the highest pressure heater to cool discharge from the water separator in the steam generator circuit. It is said to reduce flashing and give a lower cost heater

# of Latest Designs*

By J. G. MILLER and R. H. KREISINGER
Metropolitan Edison Co. Gilbert Associates, Inc.

turbine, generator and auxiliaries and front and lower part of steam generator indoors. Fig. 2 shows a section through the station with the relative elevation of the various pieces of equipment.

Steam Conditions and Cycle

The choice of steam conditions was based on the desire to utilize as high an initial pressure as could be justified for the size of the unit, but to limit the temperature to 1050 F to avoid the necessity of using austenitic-steel piping. In the initial study 3500 psi was considered but it developed that the size was too small to justify this pressure; therefore, the final choice was 2400 psi nominal pressure, 1050 F initial temperature, and 1050 F reheat temperature. The 1050 F reheat temperature over 1000 F appears to be a break-even proposition at today's fuel cost and the higher temperature was chosen in the interest of achieving a lower heat rate and anticipated long-range economic advantage. The nominal operating pressure of 2400 psi will be maintained until turbine-inlet valves are wide open, at which time the controls will be reset to increase to and maintain an operating pressure of 2520 psi in order to get additional capacity from the unit. The cycle is slightly more efficient at the 2400 psi level which is the reason for holding the lower pressure level to the limit of the inlet valves.

Seven stages of feed heating are provided in the cycle, Fig. 3, with a drain cooler above the highest pressure heater for cooling drains from the water separator in the steam-generator circuit, Fig. 5, before they are returned to the feedwater circuit. The use of this drain cooler reduces the flashing head of water entering top heater and this results in both a lower cost heater and slightly improved cycle efficiency. Deaeration is provided in both the condenser hotwell and the deaerating heater. The latter is unusual in that at full load the heater operating pressure is higher than customary for deaerator service—165 psi. The savings effected by the elimination of one closed high-pressure heater more than offset the additional cost of the higher pressure deaerator. This arrangement also has other advantages, such as less probability of high-pressure heater maintenance, and a wide range of unit loading with positive deaerator operating pressure.

The amount of the improvement effected in cycle efficiency by the use of an axial-flow exhaust turbine and side-entry condenser has yet to be determined in service. The Portland unit is the first large turbine built by the manufacturer which is designed to improve overall heat rate by (a) reduction of the leaving loss with omission of customary 90-deg bend and (b) reconversion of velocity energy in the steam leaving the last-stage wheel to potential energy in the condenser. In other words, the absolute pressure at the exit of the last-stage wheel is expected to be lower than the absolute pressure in the condenser. Detailed testing will be conducted on the unit in service to check design and to determine what actual improvement in heat rate is effected.

* Presented at the ASME Power Conference, Oct. 21–23, 1957 by the title "Axial Flow Turbine and Monotube Boiler Are Basic Design Considerations of Portland Generating Station," Allentown, Penna.

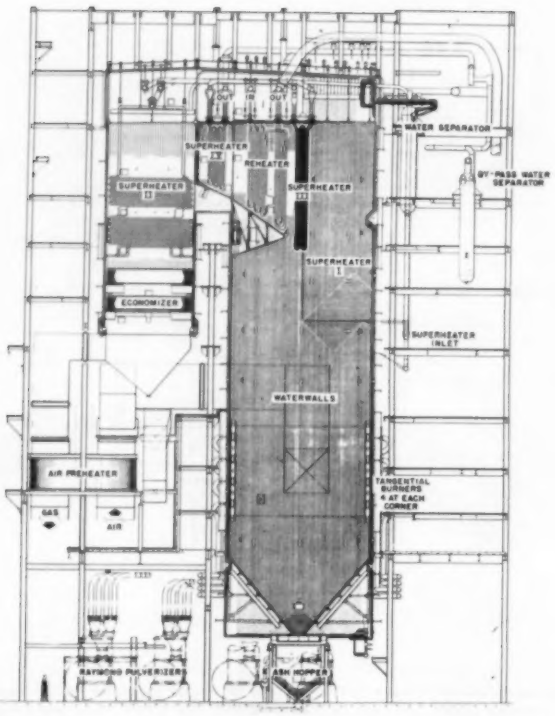

Fig. 4—Cross section of the Sulzer Monotube unit, a 1,150,000 lb per hr, 2610 psi, 1060 F, reheat to 1060 F. steam generator

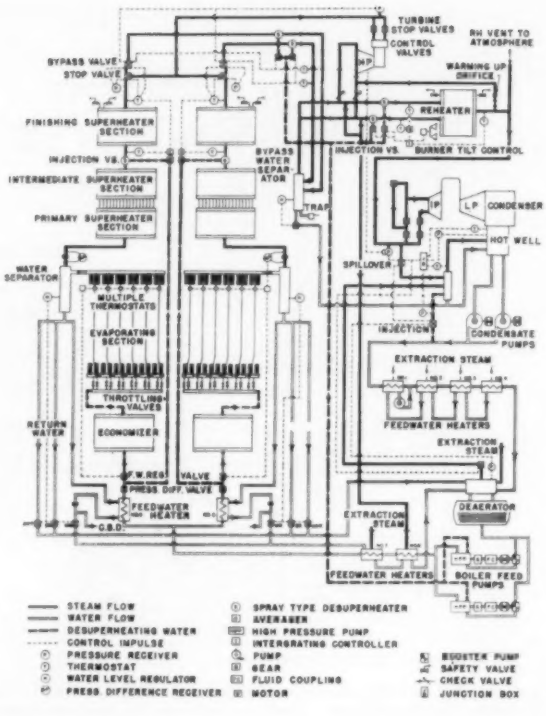

Fig. 5—Control diagram for the Monotube boiler, Fig. 3. Flow regulation is achieved by two pressure-difference and two flow regulating valves

Monotube Steam Generator

In the initial studies on Portland when 3500-psi initial pressure was being considered, negotiations with Combustion Engineering, Inc. concerning the steam generator developed considerable interest in the C.E. Sulzer design. It appeared that this type of steam-generating unit would become more commonly used in the future and that it offered certain features in starting that are becoming desirable as experience is gained with frequent shutdowns of high-temperature units. When it was decided that supercritical pressure did not seem practicable for Portland's unit No. 1 because of size, interest in the C.E. Sulzer design still remained sufficiently strong to encourage investigation of the design for subcritical pressure. The result of this study convinced Metropolitan Edison and its consulting engineers that the C.E. Sulzer unit offered advantages and had a place for subcritical pressure—thus, the decision followed to use this design for Portland unit No. 1.

The steam-generating unit is conservatively designed to deliver 1,150,000 lb of steam per hr at 2610 psi, 1060 F superheat, and 1060 F reheat with a furnace heat release of 89,000 Btu per sq ft of effective projected radiant surface. Fig. 4 shows cross-sectional view of this unit.

This Monotube steam generator has several characteristics which distinguish it from conventional steam generating units. There are no large heavy-walled drums or downcomers; however, there are three pressure vessels—two water separators and a bypass separator. The location of these vessels is not restricted to any particular elevation; however, in the case of the Portland unit there was a space advantage in locating them near the top of the furnace as shown in Fig. 4. The absence of heavy-walled pressure parts eliminates the problem of thermal stresses which restrict the operating flexibility of large conventional steam-generating units.

The water and steam side of the Monotube unit is divided into two halves each having separate controls. In the steam-generating section of the unit each half is divided into six circuits having nine $1^1/_2$-in. O.D. tubes. The flow to each of these circuits is controlled by a special sleeve-type throttling valve. Each half has its own water separator located between the evaporating section and the primary superheater. Solids are concentrated in the water separator and approximately 4 per cent of the total flow is bled back into the cycle through the water-to-water heat exchanger in the heat-balance diagram, Fig. 3.

Fig. 5 is the control diagram for the Monotube system. The water flow to the unit is controlled by two pressure-difference regulating valves and two flow regulating valves. The flow regulating valves take their impulse from one thermostat located on the outlet of the steam-generating tubes and from a steam-flow orifice located after the water separator. Any one tube in each circuit can be designated as a control tube since all tubes have a throttling valve at the inlet and a thermostat at the outlet. Only one tube in each circuit is used at a time for control and the throttling valves are adjusted so as to give this tube steam with 50 deg F superheat while the remainder of the generating tubes in the circuit produce steam with 4 per cent moisture.

Steam-temperature control is similar to that for conventional C-E units with a combination of tilting burners and spray desuperheaters. Advantage is taken of radiant superheaters as shown in Fig. 4 to give a flat temperature control over a wide range of steam flow.

Another advantage of the Monotube boiler is that it can be brought up to full pressure and the desired steam temperature rapidly. Experience with similar units in Europe has demonstrated that this can be accomplished in one hr or less. This feature is desirable in matching steam temperature to turbine-metal temperature for starting after a short shutdown, but has the disadvantage of requiring special controls, special valves, and unusual piping hook-ups that are not found in a conventional cycle. However, a bypass arrangement with a conventional unit to make possible matching temperatures on startup is just as complicated and requires as many valves. The Monotube system provides for passing a minimum of approximately 30 per cent full flow through the evaporating section of the unit during startup, and approximately 10 per cent to 30 per cent of full flow through the superheater and reheater is required to establish the desired steam temperatures.

The C-E Sulzer steam generator has been described in several papers (1–3),[1] and for more detail the reader is referred to them.

Cross-Compound Axial-Flow Exhaust Turbine

Unit No. 1 at Portland is the first large close-coupled cross-compound axial-flow exhaust turbine purchased from the General Electric Company. The low-pressure turbine is a single-cylinder unit and it has the same center line as the condenser. Fig. 6 shows an elevation of the low-pressure turbine and condenser. The turbine manufacturer has conducted a series of tests in conjunction with the condenser manufacturer to determine the shape of the turbine-condenser connecting piece for maximum recovery of velocity energy. The guaranteed heat rate makes allowances for the elimination of the 90-deg bend but not for the recovery of velocity energy, and as stated earlier, tests will be conducted to determine the improvement. The manufacturer is presenting a paper (4) describing the cross-compound axial-flow exhaust-turbine design and the Portland unit in particular.

One interesting effect that should be noted is the arrangement in elevation of the axial-flow turbine in the station relative to the other equipment. Fig. 2 shows that the turbine operating floor is 13 ft lower than the boiler operating floor and 8 ft lower than the grade elevation outside the building. The condenser height above normal water level was the controlling elevation and all other elevations determined therefrom. The turbine-foundation height is approximately 21 ft which is a substantial reduction from that normally required for the conventional turbine-condenser arrangement.

Side-Entry Condenser and Circulating-Water Supply

The choice of condenser design for use with the axial-flow exhaust turbine is most important if the expected improvement in cycle efficiency is to be achieved. To accomplish this, Ingersoll-Rand, the designer and builder, has collaborated closely with turbine manufacturer and has, as noted previously, conducted a series of tests to establish the optimum shape of the turbine-condenser connecting piece. Of necessity the condenser is of side entry type. Fig. 6 shows the overall elevation of low-pressure turbine and side entry condenser, both on the same center line. The condenser is single pass with divided water box and has 80,000 sq ft of surface. The details of the design are described in a paper (5) presented by the manufacturer.

Condenser leakage cannot be tolerated because of the feedwater purity required by the Monotube steam generator. To minimize the possibility of leakage, the manufacturer is welding the tubes in the tube sheet utilizing a new process developed by Revere Copper and Brass. Tubes are admiralty metal and tube sheets silicon bronze—two materials that tests show to be readily weldable.

The condenser hotwell has capacity equal to 10 min. full-load requirements or 14,000 gal. and is designed for maximum possible deaeration. Arrangements also are included for injection of steam from the bypass during startup of the Monotube unit, see Fig. 5. This feature is also described in the paper (5) by the manufacturer.

The two circulating-water pumps are located in the screen house, Fig. 1, and water is carried in 72-in. concrete pipes to the station and in concrete tunnels under the mat. Each pump has a capacity of 49,000 gpm and is a vertical-shaft single-stage centrifugal type. Discharge from the condenser is through a tunnel under the mat to a 72-in. concrete pipe between the building and a common discharge tunnel leading to the river. The common discharge tunnel is designed to meet requirements of planned capacity additions.

Recirculation is provided from the discharge weir chamber into the intake by a 42-in. wrought-iron pipe. The volume of recirculation is controlled by two gates—one regulating the level in the weir chamber and the other opening to 42-in. pipe.

The condenser backwashing arrangement utilizes six

[1] Numbers in parentheses refer to the bibliography at the end of the paper.

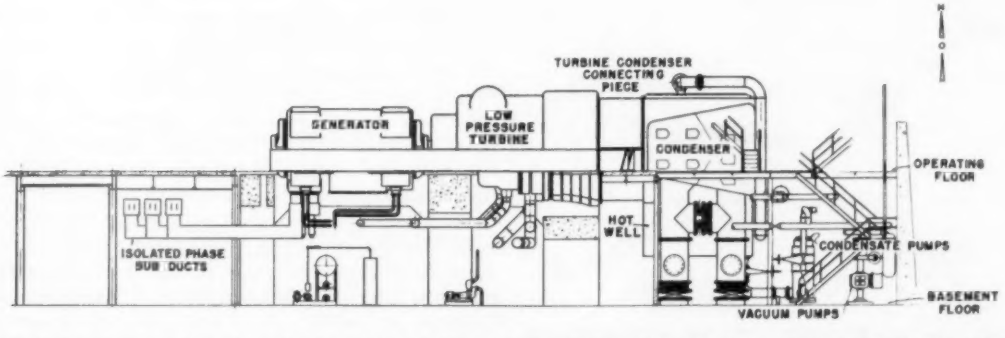

Fig. 6—Station elevation above shows that low pressure turbine, a single cylinder unit, has the same center line as does the condenser

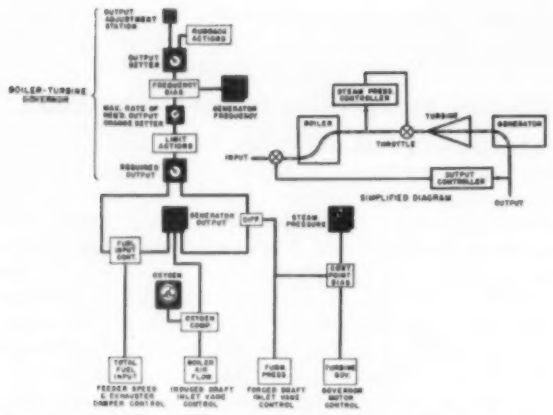

Fig. 7—Basic schematic of direct energy balance method for achieving combustion control. Unbalance between required output and actual generator output regulates the fuel input

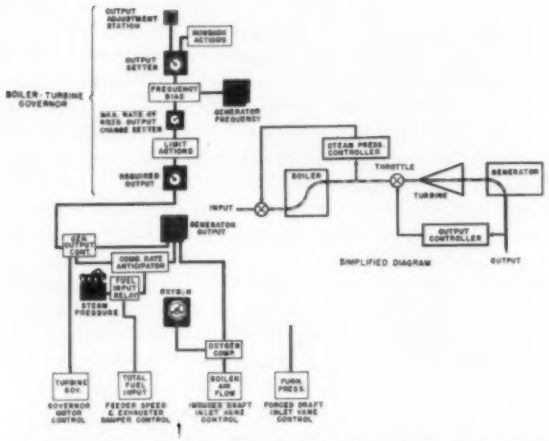

Fig. 8—So-called conventional method, above, contrasted with that of Fig. 7 regulates the turbine generator to give the required generator output while fuel to the furnace is regulated to hold steam pressure

butterfly valves instead of two specially designed backwash valves. The use of butterfly valves reduces both the first cost and the pumping charges.

Combustion Control

Two basic methods are being provided for combustion control; namely, (a) the direct energy-balance method, and (b) the so-called conventional method. Selection may be made from one to the other by transfer switch, but it is expected that the direct energy-balance method normally will be used. With the direct energy-balance method, the input of fuel to the furnace is directly regulated by the unbalance between the required output and the actual generator output, Fig. 7, the air by generator output, and the turbine governor controlled to maintain steam pressure. The energy input to the furnace is directly controlled to give the desired generator output and the turbine keeps in step with the steam-generator output. The so-called conventional method, Fig. 8, regulates the turbine governor to give required generator output while the energy input to the furnace is controlled to maintain steam pressure. Combustion-rate anticipation is obtained from generator output plus regulation applied to turbine-governor motor. With this arrangement the steam generator follows the turbine demand. A detailed description of this control is described in (6).

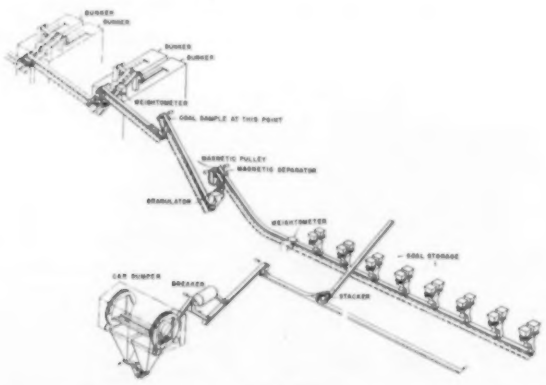

Fig. 9—Isometric view of coal-handling system emphasizes design aim of minimum size bunkers and heavy use of an active outdoor storage

Coal Handling

The basic idea in design of the coal-handling system was to provide minimum size bunkers and a large active storage outside with automatic control of the handling system to transfer coal by belt from the active pile to the bunkers. Fig. 9 shows the arrangement of the system. Cars will be unloaded by a rotary dumper which will be equipped with scales for weighing incoming coal. From the car-dumper hoppers, coal is transferred through a Bradford breaker to a traveling tripper and stacker to the active pile located over series of hoppers. The system to this point is controlled by an unloading crew.

From active pile to bunkers, the system is under control of the operating crew in the station. Coal is fed onto a belt in the reclaim tunnel under the active storage pile by vibrating feeders, the number operating at any one time being controlled by the operator in the control room. For the ultimate station the system is planned as follows: When coal reaches the dividing hopper at the end of Unit 1 bunker, part is fed by a vibrating feeder to the belt supplying Unit 1 bunker, part by a vibrating feeder to Unit 2 bunker, and the remainder spills over to the belt leading to a dividing hopper at end of Unit 3 bunker. Here coal is again divided in the same manner between Units 3 and 4 bunkers and the belt leading to Units 5 and 6. The amount of coal fed onto the belt to Unit 1 bunker is controlled by a belt scale which in turn controls its corresponding vibrating feeder. The belt scale is set to control at desired rate by the control room operator. In the same manner, a controlled amount of coal is fed to all the other units. A summation of the set amounts on the individual bunker belt scales is transmitted to the scale on the main belt which in turn automatically controls the amount of coal being fed onto this belt by the vibrating feeders under the active storage pile.

Each bunker is equipped with high and low-level controls and alarms. The latter are in the control room. Initially with only one unit in service, the system will be operated intermittently to keep coal within high and low limits in the bunker. After three units are in service, it is expected the system will run continuously.

The automatic control system acts through the scales and vibrating feeders only and does not stop and start the belts. It is planned to operate the belts continuously.

The system is designed for installation of a second belt in the future from the active storage to the bunkers. Provision has not been made for a second belt to active storage because in case of a failure, storage coal can be used until repairs are executed.

The capacity for the initial installation of the active outdoor storage pile is approximately 7000 tons and the capacity of the bunker for Unit 1 is 600 tons. The bunker is unlined and is made of corrosion-resisting mayari steel plate with stainless-clad plate in the noses.

Exhaust Gas System and Ash Collection

The problem of atmospheric pollution is a serious one and while Portland is not near any center of population it is located in a resort area. For this reason equipment is provided to reduce pollution to an absolute minimum.

Fly ash is collected by a combination mechanical and electrostatic unit with a guaranteed overall collection efficiency of 99.0 per cent. Ash is transported by a vacuum system from hoppers under the collectors to a silo. Vacuum is produced by an hydrovactor, but an air washer is installed ahead of the hydrovactor to prevent fine ash from entering the water stream and being carried into the river. Sludge from the air washer is discharged to a settling basin, Fig. 1. Initially the ash will be hauled away by truck but in the ultimate station, transportation may be either by truck or railroad.

Because of the necessity of keeping air pollution to a minimum in the area around the station, a study was made of chimney height relative to surrounding terrain. The height recommended and accepted is 400 ft. The chimney is constructed of reinforced concrete.

Water Treatment and Control

Fans

Since the fly-ash collection efficiency is high and the gas to the induced-draft fans contains very little ash, it was decided to install airfoil fans with an efficiency of 85 per cent. This resulted in a saving of 400 hp in fan motors which more than offsets the added cost of the airfoil fans. The forced-draft fans also are airfoil design.

Each ID and FD fan is driven by one motor. Inlet vanes control combustion air and furnace draft.

Deaeration

In the modern high-pressure power plant control of the feedwater in the cycle has become of critical importance. This is true even with the conventional steam generator with the large drum and comparatively large storage of water. For the Monotube or once-through type of unit the feedwater condition is even more critical. The presence of oxygen cannot be tolerated in any high-pressure cycle, but in the Monotube unit where the use of scavengers may be somewhat less effective than usual, deaeration is even more critical. For this reason, in addition to a deaerating heater, the condenser hotwell is of the reheat-deaerating type with storage capacity equivalent to a 10-min flow at design condition and a maximum oxygen content in the condenser of 0.01 cc/liter.

Blowdown

The cycle heat balance, Fig. 3, is conventional except for the two water-return heat exchangers. The feedwater flow is divided after passing through the top heater and remains separated until after it passes the two boiler steam stop valves. Cycle blowdown is removed from each of the water-separator drains after passing these heat exchangers. Remaining drains are flashed at

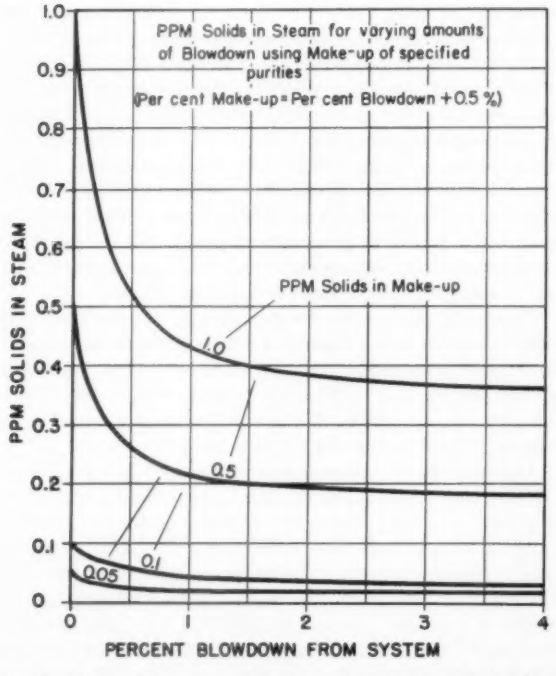

Fig. 10—Relation between steam purity, makeup purity and blowdown comprise the data portrayed on the graphs above

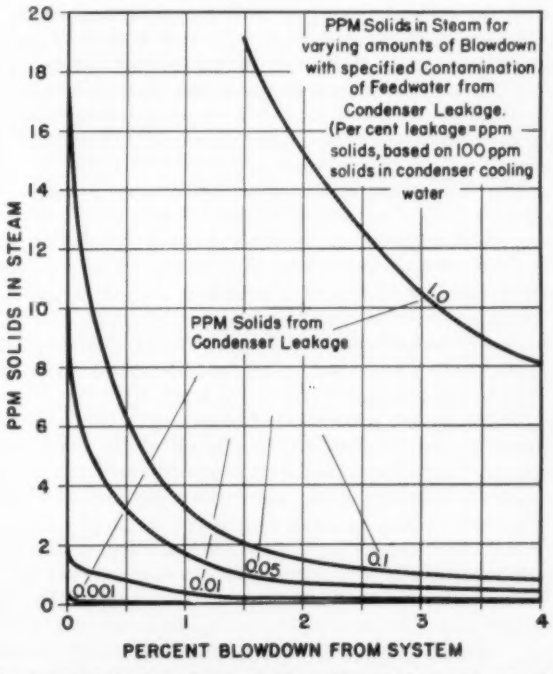

Fig. 11—Marked effect of even small condenser leakage shows in the values of the water properties pictured in Figs. 10, 11

deaerating-heater pressure and at 21st-stage pressure and the water remaining is discharged to waste. If this water has satisfactory chemical anslysis (low in iron) it also may be saved.

The Monotube boiler requires a high degree of feedwater purity and, therefore, this has been the dominating factor governing the choice of feedwater treatment. This boiler can tolerate 0.5 ppm total solids, but since the steam purity will not be significantly better than the feedwater purity, the total solids will be limited to 0.25 ppm with 0.02 ppm maximum silica content in order to protect the turbine. The concentration of the separated boiler water (4 per cent of steam flow) is expected to be about three times that of the feedwater, and this makes it possible to purge the system by blowdown.

Fig. 10, which was prepared by Combustion Engineering, Inc., shows the relation between steam purity, makeup purity, and blowdown. The curves indicate that even without blowdown from the system, satisfactory steam purity exists with make-up of 0.1 ppm total solids or less. This is due to the fact that solids are lost from the system with the 0.5 per cent loss of steam and water in the cycle. When solids in the makeup exceed 0.2 ppm some blowdown is necessary. Satisfactory results can be obtained with 0.5 ppm total solids in the makeup provided about 1 per cent blowdown is maintained. This will remove nearly 60 per cent of solids introduced into the system. Should the makeup reach 1 ppm even 4 per cent blowdown would not be sufficient. Based on this information, the make-up requirements were set at 0.1 ppm total solids and 0.02 ppm silica maximum. Treatment equipment is sized for 1 per cent normal makeup and 5 per cent maximum.

Condenser Leakage

The curves in Fig. 11, also prepared by Combustion Engineering, Inc., show the marked effect of even very small amounts of condenser leakage. Contamination of 0.05 ppm solids from leakage will require about 1.5 per cent blowdown in order to maintain steam purity at 1 ppm which is considered the maximum that should enter the turbine. If the river water contains 100 ppm total solids (a figure which is exceeded during some seasons) 500 lb per hr condenser leakage is the most that can be tolerated. Expressing all this in a different way, 1 ppm total solids in the feedwater will require a shutdown in 8–10 hr; 5 ppm will require an immediate shutdown to correct the trouble. While blowdown is effective in eliminating solids from the system, it is apparent that an absolutely tight condenser is extremely desirable.

In order to provide a condenser to meet these requirements, the tubes are welded to the tube sheets. The decision to use this construction was made after investigating and rejecting several other proposed methods for insuring a tight condenser. Nearly all of the condenser manufacturers expressed confidence in their particular variety of rolled joint, but there was reluctance to accept this construction. In the first place, even those companies which report no trouble with condenser leakage, admit that the boilers must be blown down. This blowdown is necessary because of small amounts of condenser leakage that can be accepted with a conventional boiler, but could not be tolerated with a Monotube boiler. Furthermore experience has demonstrated that some tubes which have been electronically rolled will work loose in the joint within a week after rolling. Double tube sheets were considered, but were found undesirable because of high cost and the possible trouble with differential expansion unless the adjacent sheets were widely spaced. The use of coatings, such as neoprene, while not rejected as a method of protecting tube ends and tube sheets, did not seem to offer as much assurance of a tight condenser as did the welded design. The welding process was chosen after investigating samples and methods of several manufacturers. Revere Copper and Brass seemed to have done the most research on the welding of condenser-tube materials and their welding process seemed to be the most highly developed.

Chemical Feedwater Treatment

Chemical feedwater treatment will consist of hydrazine for oxygen scavenging and ammonia for pH control. Since little can be expected from hydrazine in the condensate and feedwater system, the dissolved oxygen must be kept low. For this reason, the condenser will deaerate to 0.1 cc/liter and the deaerating heater to 0.005 ppm—about the best deaeration that can be obtained commercially today. Morpholine is preferred for pH control because of its better distribution ration and consequently better turbine protection, but there has been little experience with morpholine in Monotube boilers, and there is considerable concern with the products of decomposition which might result. As a result the unit will be started with ammonia used for pH control.

Water Treating Equipment

The requirement for make-up water containing total solids of the order of 0.1 ppm can only be met by double evaporation or demineralization, and the latter seems to be the more practical solution. The water-treating equipment is two demineralizer chains, each consisting of a cation unit, an anion unit, and a mixed polishing unit. A vacuum degassifier, common to both chains, is installed between the cation and anion units. All units are provided with semi-automatic regeneration.

Each chain is designed for a normal flow rate of 23 gpm and a maximum of 60 gpm. The degassifier is rated 180 gpm. Each cation exchanger has capacity of 50,000 gal between regenerations, plus 9000 gal additional for regeneration of one anion and one mixed bed. Each anion exchanger is expected to produce 50,000 gal between regenerations, plus 5000 gal for one mixed bed. Each mixed bed is expected to produce approximately 225,000 gal between regenerations. A flow diagram of the water-treating equipment has been developed.

Water supply for the demineralizers will be from wells with the river as an emergency source. Pretreatment is to consist of prefloc added in a mixing flume, anthrafilt gravity filters, and a 150,000-gal filtered-water clear well. Alkali and alum will be added in a flash mixer ahead of the mixing flume when river water is used.

Demineralized makeup water is stored in two 21,000-gal unlined 40-psi Code tanks. The effluent of the demineralizers flows directly to the condensate storage tanks. Water from the cycle enters the tanks from the main condensate-pump discharge and reenters the cycle through the condenser. While in the tanks it will be kept under a nitrogen blanket to prevent air contamination and tank corrosion. Nitrogen is fed and tank pressure controlled primarily by the operator, but will be fed in automatically if pressure drops below about 1 psi.

House-Service System

In order to prevent high maintenance costs and inefficient heat transfer, the house-service cooling system is a completely closed cycle. It will be charged with demineralized water treated for pH control and cooled by river water in a heat exchanger.

Generator cooling also is accomplished in a closed cycle charged with treated demineralized water. Normally this water will take heat from the generator hydrogen coolers and reject it to the condensate. During the summer months when the condensate is too hot to accept this heat, it will be rejected directly to the river through one of the two house-service heat exchangers.

In order to minimize iron contamination of the main feedwater cycle, the building heating cycle is separate and closed. An evaporative-type heat exchanger is installed to a transfer heat from the turbine cycle. An oil-fired package boiler also is installed for use before startup and when the unit is off during cold weather. After additional units are installed this boiler will be removed.

The 150,000-gal filtered-water clearwell has been sized to handle all of the water requirements of the station including fire protection. For the latter purpose there is installed one motor-driven and one diesel-driven fire pump each discharging directly into the fire main. There also will be an elevated 25,000-gal filtered-water tank which will keep the fire mains charged, provide a ready water supply for the transformer fog nozzles, and supply certain miscellaneous pump glands.

Boiler Feedwater Pumps

Reliability of boiler feed pumps in service has been proven by experience in many installations and because of this record only two half-sized pumps are installed with Portland Unit 1. Space has been provided for a third pump if experience with the Portland pumps should be the exception and require the third pump to keep full capacity available. Estimated saving by elimination of a third pump is more than $200,000.

The pumps, which are being built by Worthington, consist of an 1800-rpm booster pump directly connected to the motor drive and a high-speed (6800-rpm) pump driven through a hydraulic coupling and step-up gear. The use of the booster pump permits a much lower NPSH which in turn makes possible moderate saving by lowering of the required deaerating-heater elevation. The high-speed pump was favored over the 3600-rpm pump because it is believed that the appreciable lesser number of stages and shorter and more rigid shaft will be more reliable. Other reasons which favor the high-speed pump are treated in recent papers (7) on this subject.

Feedwater Heaters

As shown in Fig. 3, seven stages of extracting heating are provided with No. 8 heat exchanger located above the high-pressure heater to serve as a drain cooler for the drains from the water separator in the steam-generator circuit. Feedwater heaters Nos. 1, 2, 3, 4, 6, and 7 are vertical closed-type heat exchangers and all except No. 1 with drain-cooler section. The No. 8 high-pressure heat exchanger is also vertical type. These heat exchangers are all constucted with welded shell joints. The heads of heaters Nos. 6, 7, and 8 are seal-welded and the tubes are welded to the tube sheet. The high-pressure heater-tube material is monel metal. Admiralty tubes are used in the low-pressure heaters. All closed feedwater heaters and heat exchangers are by Griscom-Russell Company.

The No. 5 feedwater heater is a deaerating type and is designed to operate under maximum pressure of 165 psi. This heater was purchased to give maximum deaeration and is guaranteed to produce water with oxygen content of 0.005 ppm. The deaerating heater was supplied by American Water Softener Company.

Conclusion

Even though the first unit at Portland includes: (a) a Monotube boiler, which is new in this country; (b) a new turbine design and a new turbine-condenser arrangement; and (c) a combustion control which involves a new concept; it is not expected that the total cost will be appreciably different than if present-day conventional design with the same steam conditions had been followed. The estimated total cost, including land and substation, is $25,902,000 or $157 per kw based on 165,000 kw capacity.

That there will be problems in the initial startup at Portland goes without saying, but these are not expected to be particularly unusual or even appreciably more complicated or difficult than would be encountered with more conventional types of equipment. Based on the past competent achievement of the various suppliers of equipment, there is reason to expect Portland to be in commercial operation within a reasonable time after the initial startup.

Acknowledgment

The design and construction of Portland Station is not a one man or one company achievement. The cooperative efforts of the manufacturers, Gilbert Associates, Inc., and the Metropolitan Edison Company have been essential to the carrying out of this project. It is appropriate, therefore, to express appreciation to all who have contributed and also to those who assisted in the preparation of this paper.

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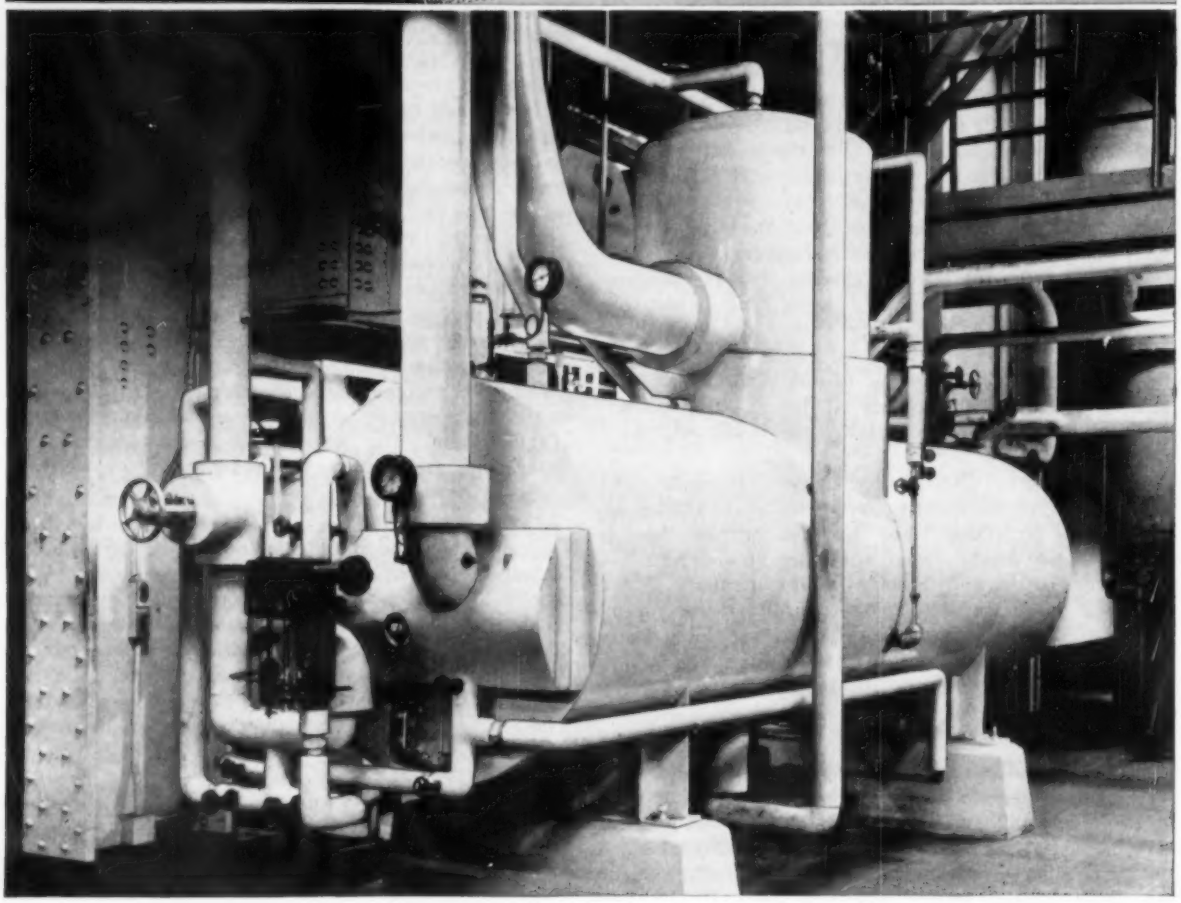

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Power Practices in 1957

ONCE again new peaks were established in the areas of electric energy produced and electrical generating capacity installed. Specifically the new totals are. (1) the highest 12-month (October 1956–September 1957) electric energy production ever established by the public utilities—nearly 627 billion kwhrs—better than 5.9 per cent above the roughly 592 billion kwhr figures for the same October to September a year ago; however, the month of September, 1957, produced 7.0 per cent less kwhr (51.6 billion) than did August, 1957 (55.45 billion), (2) a combined utility and industrial energy production that reached 5.5 per cent above that of the same 12-month span in 1956 to about 712 billion kwhrs, (3) a utility and industrial generating capacity that aggregated 143,034,774 kw on September 30, 1957. All the foregoing are based on the latest available Federal Power Commission reports. This same source further puts installed capacity of utility generating plants at 126,240,051 kw on September 30, 1957 as against 118, 660,912 kw reported in service on September 30,1956. Industrial generating capacity, according to the FPC, rose slightly from the 16,466,126 kw level as of September 30,1957. This industrial capacity includes the stationary plants of electric railroads and railways.

Capacity Additions

Manufacture of heavy electric power equipment continues at a high rate according to the Twenty-Second Semi-Annual Electric Power Survey of the Edison Electric Institute. Scheduled production for shipment in 1958 stands at an all time record of 17.8 million kw, 90 per cent of which is for U. S. electric power systems. The Twenty-Second Survey indicates that the total capacity of new generating units placed in commercial operation since the beginning of 1957 will be about 5.5 million kw.

Capability of the electric power systems is estimated to reach over 131,000,000 kw by the end of 1957, an increase of almost 7.0 per cent for the year. The scheduled capability at the end of 1960 will exceed 171,000,000 kw, which the E.E.I. Survey points out, is an annual average increase of 8.2 per cent from the end of 1955.

Peak load for the country as a whole still occurs in December and this year it is believed it will go to about 112,000,000 kw. The December 1960 peak E.E.I. estimates at about 141,000,000 kw and as such it represents an average annual increase from 1955 of 7.6 per cent.

The E.E.I. feel their latest survey indicates electric power requirements throughout the United States will continue to show substantial increases during the next few years. Further, E.E.I. believes the already scheduled expansion by the electric power systems of the country is ample to keep pace with these growing demands and at the same time maintain adequate margins.

Thermal power projects in the E.E.I. compilation on order and scheduled for shipment as of October 1 constitute 91 per cent of the scheduled generating capacity expansion and the remaining 9 per cent is hydro. The size of thermal generating units continues to increase. Last year's report indicated two thermal units with manufacturer's ratings of 450,000 kw. The largest unit now on order is rated at 500,000 kw.

During the past few years, owing to a growing use of air conditioning, summer loads on all systems have improved. The 1957 summer peak load was 106,700,000 kw, or 8.9 per cent over the 1956 summer peak. In 1960 the summer peak load is estimated to reach 137,000,000 kw, an annual increase from the summer of 1955 of 8.6 per cent.

Gross margin for the United States as a whole is expected to be 16.7 per cent in December 1957 and forecasts for December of the years 1958 through 1960 are 20 per cent. Summer peaks for the country as a whole still lag December ones. But, except in Region III, it appears as if the summer peak load expressed as a percentage of the winter peak load for the same year is increasing. As an example the 1957 prediction is for 95 per cent; 1958, 96 per cent and 1960, 98 per cent.

Nuclear Power

The late October meeting of the Atomic Industrial Forum produced a very significant insight into the immediate future of nuclear energy development within the U.S.A. There is no escaping the long term prospect of higher conventional fuel costs and hence the certainty that nuclear power must increase in importance. Yet both the electric generating industry and the major equipment manufacturers find the present disparity in cost between nuclear and conventional power to be a most severe deterrent to an accelerated development program. One speaker, from a major industrial, felt the "Government must recognize the limitations of American industry and support it in a more positive and thorough manner than in the past." Further many believed a government-industry partnership is the ideal solution to the future. One that would permit American participation in European and Japanese projects where the energy requirements are more urgent and fuel is more costly is

the ideal outlet for a growth in operating experience without unduly hobbling industry at home.

The Forum itself had engaged a consultant firm to delve into the future and this firm presented at the Forum a preliminary report on two major aspects, capital equipment and fuel cycle functions. A continued effort comparable to that now planned for capital equipment could result in an economic plant in 1954, at the earliest. Less optimistic assumptions would produce such a plant in 1968. The maximum range the consultant foresees is 6,000,000 nuclear electrical kw operating by 1968 while the minimum figures to be expected would be but one-third that quantity. These represent about 2.1 per cent for the maximum and 0.7 per cent for the minimum of the expected U.S. electrical capacity in 1968.

On the subject of fuel costs a large water type reactor was employed as the yardstick. This reactor using UO_2 slightly enriched and an operating date of 1960 recorded an expected range for fuel costs of 8.4 mills per kwhr maximum to a 5.6 mills per kwhr minimum.

Fuels

Mine output of bituminous coal for 1957 was estimated to approximate 490 million tons. Overseas exports, however, registered a healthy 58 million tons, up 20 per cent over last year's. The electric utilities in 1956 consumed 159 million tons or better than 1 per cent above last year's 157 million high, expected to go to 165. In the power generation field the TVA plants alone used 18.5 million tons and the atomic energy project suppliers in total required around 20.5 million tons.

Keystone Coal Buyers Manual, a McGraw-Hill publication, predicts that the electric utilities will burn $8^1/_2$ per cent more fuel next year than they consumed during 1957.

The utilities' consumption of gas will go up 11 per cent, coal up 6 per cent and oil up 5 per cent. Nuclear fuel will record a noticeable contribution for the first time in history.

The big increase in gas consumption is ascribed to fast utility expansion in the Southern border states where gas is in abundant supply, and to a switchover in certain dual gas oil plants in favor of gas. An eight-year projection of the study reveals a continuing trend of increased fuel consumption with coal going up about 54 per cent, gas at 80 per cent and oil at 30 per cent.

The table below shows the year-by-year increases by fuel and also includes the nuclear time table (estimated) which was not a part of this survey:

	1957	1958	1959	1960	1961	1965
	(Millions of Tons Coal or Coal Equivalent)					
Coal	162	172	182	194	207	249
Gas	54	60	68	75	79	98
Oil	20	21	19	18	19	26
Nuclear	0	0.1	0.42	1.5	2.8	15.0

Gas Turbines

Gas turbine generating capacity expected to be delivered in 1957 and 1958 throughout the world is estimated to be about 780,000 kw while the total delivered during the past 11 past years up to and including 1956 was 566,000 kw. These figures do not reflect the even more rapid growth in the use of these gas turbines for mechanical drive and process applications.

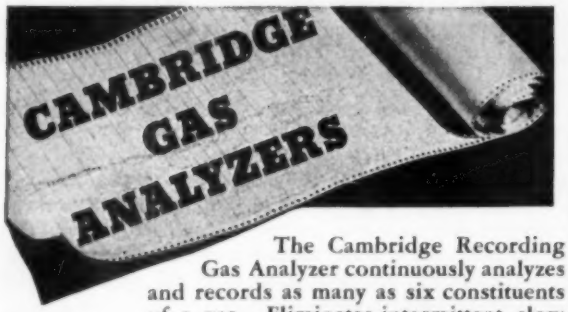
It has been pointed out and quite effectively that a combined steam and gas turbine plant offers advantages in overall heat rate that a conventional plant cannot match. The exhaust from a gas turbine contains approximately 80 per cent of its original oxygen and hence used as a combustion air in an essentially standard pressurized boiler permits firing any available fuel in the main boiler with only that quantity needed by the gas turbine itself to be gas or oil.

When the installed costs of such a combined cycle is compared with a steam cycle of equivalent capacity there would be a savings in unit cost per kw approaching 6 per cent depending, of course, on size. The pressurized closed cycle gas turbine will result in a machine whose thermal efficiency is approximately independent of load throughout the full load range.

James Landis Elected ASME President

James N. Landis, vice president of Bechtel Corp., and a past chairman of both the San Francisco Section of the ASME and of its Metropolitan Section in New York was installed as president of the 50,000-member Society.

Other successful candidates for the posts of regional vice presidents and directors were: Charles E. Crede, vice president, Barry Controls, Inc.; Arthur W. Weber, vice president, Corning Glass Works; Ernst W. Allardt, Chief Engineer, The Babcock & Wilcox Co., Tubular Products Div.; Henry S. Aurand, Lieutenant General, U. S. Army, Ret., Honolulu, Vice President Region VII; L. N. Rowley, Jr., Editor, *Power*, Elmer O. Bergman, Staff Consultant, C. F. Braun & Co.; Ronald B. Smith, Vice President, The M. W. Kellogg Co.



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The need for reliability and the possible savings in installation and operating costs justify careful hydraulic design for the typical power plant's condenser cooling cycle. This paper discusses some of the system hydraulic features which require special attention. Among these are the economics of pumping, the calculation of pumping head, the hydraulic design of pump suction chambers, maximum siphon recovery, air binding and water hammer.

By R. T. RICHARDS

Ebasco Services, Inc.

Circulating Water Systems of Steam Power Plants*

CIRCULATING water systems for condensing steam at the turbine exhausts of steam power plants require very large and often complex water-pumping installations. The desirability of careful mechanical and hydraulic design becomes apparent when one considers the very large quantities of water which must be moved through a large condenser. A water use of $1^1/_2$ cu ft per sec per 1000 kw will result in a total requirement of 300 cfs for a 200,000-kw unit. This is 135,000 gallons per minute or, in terms of water works practice, 194 million gallons per day, enough water to supply domestic and industrial needs for a city of over a million and a half people.

There are many factors which the designer must consider if he is to provide such quantities at the least possible cost and with the least difficulty in operation. Safety must also be considered because of potentially serious water hammer surges which may occur in some systems.

For convenience of discussion the major hydraulic considerations in circulating water system design may be set forth as follows:

(1) Economics of pumping.

* Paper prepared for presentation before the American Society of Civil Engineers, Power Div., October 1957 and published as Paper No. 1488, December, Journal of the Power Division.

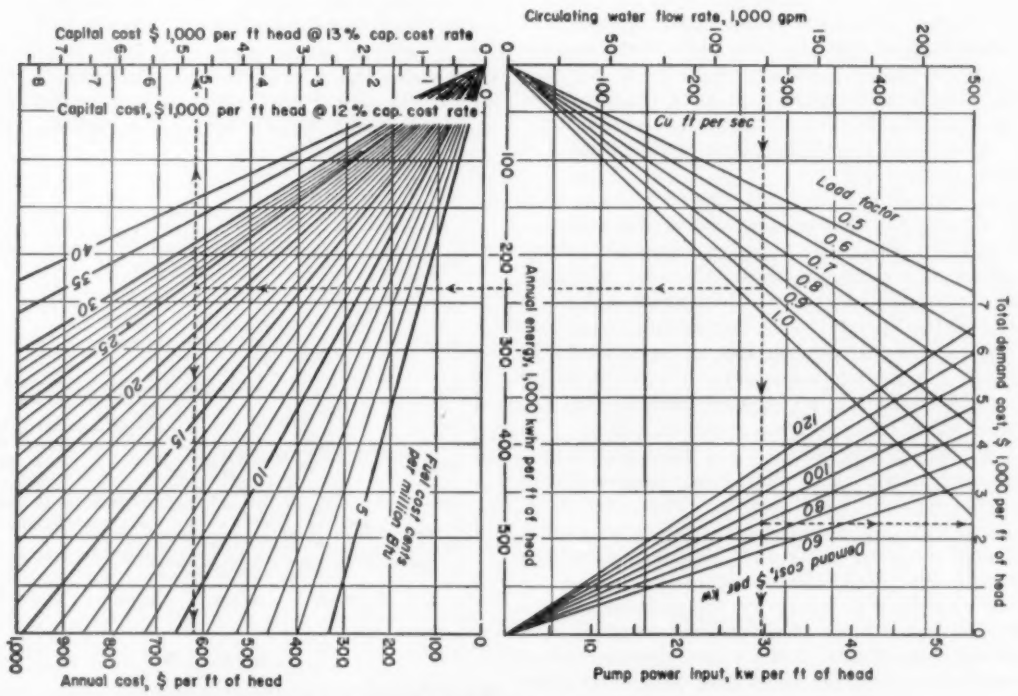

Capital cost $ 1,000 per ft head @ 13 % cap. cost rate
Capital cost, $ 1,000 per ft head @ 12 % cap. cost rate
Fuel cost, cents per million Btu
Annual cost, $ per ft of head
Circulating water flow rate, 1,000 gpm
Cu ft per sec
Load factor
Annual energy, 1,000 kwhr per ft of head
Demand cost, $ per kw
Total demand cost, $ 1,000 per ft of head
Pump power input, kw per ft of head

Fig. 1—Approximate cost figures for pumping circulating water can be picked from above

(2) The circulating water system layout, including conduit plan and profile, location of intake and discharge, design of hydraulic shapes to minimize head losses.

(3) The selection of pumps, with particular attention to the determination of the proper design pumping head, and to pump operation at heads below and above the design point.

(4) The pump structure and the proper guidance of flow to the pumps, especially critical for suction chambers supplying vertical pumps.

(5) The setting of the seal well or final discharge point to obtain maximum siphon recovery.

(6) Air binding and conduits under vacuum.

(7) Water hammer possibilities.

The Economics of Pumping

The economics of pumping water is one of the first considerations in the design of the circulating water system. The design details are influenced by several cost relationships, among which are the following:

(1) The investment costs of the pump and motor increase as the head increases.

(2) As the conduit size is decreased the construction cost also decreases, but because of the resulting increase in friction and in total pumping head the pumping costs rise.

(3) When refinements of water passages are being considered pumping costs will usually be decreased as the cost of making the refinements is increased.

Taking these factors into consideration we have some of the yardsticks by which we can measure the desirability of a particular circulating water system design.

As an example, let us determine the proper size for a 3000-ft length of straight pipe carrying a fixed quantity of water continuously throughout the year. A chart can be prepared wherein the costs of purchasing and installing the pipe are added to the costs of pumping the water and providing the extra power capacity in the power plant ("demand" cost). The most economical pipe size gives the minimum sum of these factors. However, the simplicity of this calculation is often complicated by the variation of conduit flow during the year or the variation over a number of years as more units are added to the system. Neither the size nor installation date of future units is available in many cases.

The cost of moving a large quantity of water against one foot of head may well be such that considerable expense is justified in making a design refinement which would reduce this pumping head. Consider a typical 200,000-kw unit using 300 cfs. With a fuel cost of 20 cents per 1,000,000 Btu and with continuously operating pumps the capitalized cost per foot of head would be about $5000. To this add a demand cost of $2600, giving a total of $7600 which is a rough measure of what the designer can afford to spend to save one foot of head.

Fig. 1 is a chart from which these approximate cost figures were obtained. This chart was prepared by the author and originally published in *Power*, February, 1956. It permits the rapid determination of capital costs, annual pumping costs and "demand" costs per foot of head. Starting at the top right-hand side of the chart with a known water quantity, one proceeds as indicated by the dotted lines. The demand costs are read from the right-hand side of the chart, the annual and capital costs from the left-hand side, bottom and top respectively.

Circulating Water System Layout

The most suitable circulating water system has an intake located on a lake, river or tidal area in such a manner as to obtain the coolest, clearest water and a discharge located to prevent warm water recirculation (except as specifically provided for in cold climates). Such location is a major study in itself and is not within the scope of this paper. The author is concerned here with designing the most efficient conduit system to move water between predetermined points of intake and discharge.

The major concentrations of head loss are usually at three points in the system: at the pump discharges, at the piping entering and leaving the condenser, and at the final discharge structure. At all these points numerous changes in direction and velocities occur.

Every effort should be made to reduce the number of abrupt transitions, bends and obstructions within the system. It is also worth while to consider the use of diffusers at the pump discharge, at the outlet of the condenser piping into the main conduit, and at the final discharge. A diffuser is a gradual increase in the water passage area which permits recovery of some of the velocity head. At bends a vaned elbow, common in wind tunnel work and discussed below for pump suctions, may be a worthwhile head saving device where lack of space requires sharp bends or a series of bends in different directions. Whether the use of diffuser, vaned elbows or other refinements is justified is a matter of economics—the cost of the refinement compared with the expected reduction in cost of pumping.

Pump Design Operating Heads

The determination of the proper design head for a circulating water pump requires consideration of many factors. The friction coefficients in large size conduit are not the same as those customarily used for small (12-in. and less) water piping. They are usually much smaller in large conduits and therefore result in less friction loss. Also, the intake water level at many plants varies over a wide range, as at river and tidal sites. The selection of the proper water level for pump head design requires a careful study of seasonal variations. It is not

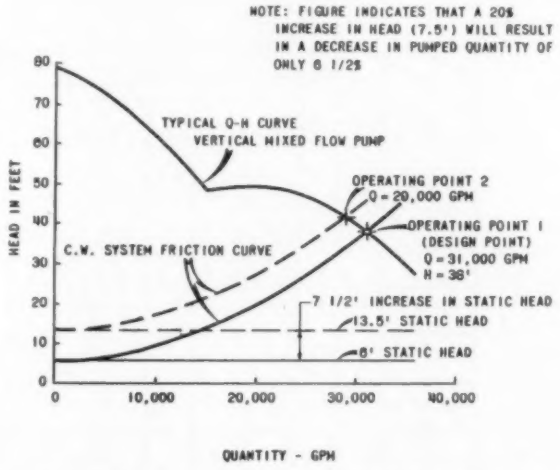


Fig. 2—Establishing desired head for pump involves study of intake head, conduit friction, quantity flow

usual practice to design the pumps for the extreme low-water condition.

The intake water level assumed for pumping head calculations should be carefully considered so that the pump will operate as close to its design point as possible over the majority of its operating life. Using as an example a typical quantity-head curve for a mixed flow pump it may be seen from Fig. 2 that if the intake water level should drop such that the original calculated head was exceeded by 20 per cent the actual loss of flow would be only $6^1/_2$ per cent, possibly not serious if occurring at rare intervals. It must be kept in mind, however, that extreme low water should be used when determining the depth of the intake structure and the length of vertical pump to insure that the pumps can draw water always.

The author's experience and information gained from the major pump manufacturers clearly indicate that the underdesigned pump is rare and that overdesigned pumps are the rule. The result is not conservative pump design, but a design that is wasteful of power and may result in premature failure of the pumps. As the pump operates farther out on its quantity-head curve it requires a greater submergence which is not always available. The result may be cavitation at the impellers with resulting destructive pitting. Even with ample submergence the pump may operate roughly at extreme runouts.

Submergence is defined as the depth of water over the pump impeller or, as more commonly specified, over the bottom of the bell. Pump manufacturers should be requested to provide not only a recommended submergence at design point, but a curve of required submergence covering the entire operating range of the pumps.

With pump heads properly determined there still may be operating procedures which will unduly strain the pumps. Operating a reduced number of pumps through all condenser shells on the system may result in an undesirable pump runout. This should be investigated in design and the operators alerted to its undesirable effects.

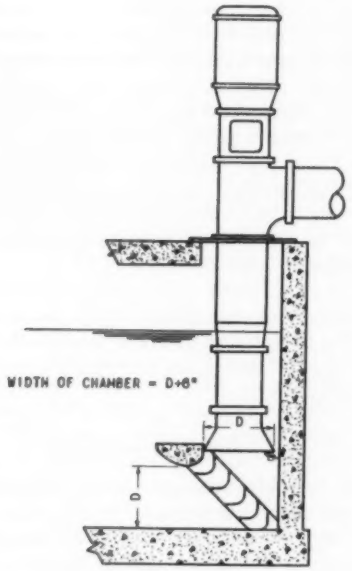


Fig. 3—Carbon steel or a metal less prone to corrosion serves as a vane material to effect a balanced flow to the pump

The Pump Structure

Pumps are sensitive to the flow patterns at their impellers. Horizontal and vertical centrifugal pumps generally present only minor problems since a length of suction pipe will often properly distribute the flow. But with vertical axial and mixed flow pumps the problem is acute. Even with the best of care in designing the flow approach, vortices may form and draw air into the system. Rough and often damaging pump operation results and air may also cause pitting problems in condenser tubes. In a poorly designed intake general hydraulic unbalance at the impellers may result in rough operation, pitting due to cavitation and excessive bearing wear even if no vortices are present.

The designer must rely on his own experience, model studies and the recommendations of the pump manufacturer in laying out the structure. Unfortunately there is a wide divergence of opinion among the major manufacturers of large vertical pumps as to what constitutes a proper suction chamber. Where construction space permits, the manufacturers recommend a structure with straight sides (for a distance of say 10 pump bell diameters) and a horizontal bottom. But recommendations for side, bottom and back clearances for the pumps vary widely for similar pumps. The author has investigated irritating flow problems in chambers approved in detail by the manufacturer and therefore assumed to be in accordance with best practice.

There have been many attempts to insure balanced flow to the pump impellers by specifying various types of baffles, suction tubes and turning vanes but these have not proven to be cure-alls.

At recent installations the author's firm has used a vaned elbow under the pump bell, consisting of a set of five to eight horizontal turning vanes, which guides the flow up into the pump. A typical elbow is shown in Fig. 3. Vanes are made of carbon steel or sometimes a metal less subject to corrosion. Six major plants now in operation and several under construction have pumps so equipped. The elbow permits the use of a pump bay only a few inches wider than the pump bell itself (as compared with two pump bell diameters normally recommended). To offset this advantage, however, the chamber must be deeper. Hydraulic performance has been satisfactory, both in new installations and in those where the elbows have been installed to correct existing poor hydraulic conditions. The vaned elbow is not a solution for all intake design problems, but it has proved its value in many cases and is approved by at least two of the major circulating water pump manufacturers.

Where pumps cannot be installed in the ideal straight-sided chamber, as in many additions to old plants, there is no substitute for model tests to determine the proper design for hydraulic passages.

Maximum Siphon Recovery

For all but cooling tower installations the final discharge point for the circulating water system will be well below the condenser, resulting in a section of the system

operating as a siphon under less than atmospheric pressure.

If the plant is high on a lake shore or river bank, the lower the discharge point is set, the lower will be the pumping head as the static head is reduced. The limit to reduction of pumping head is the maximum siphon or amount of vacuum which can be permitted in the system.

The measure of vacuum is the vertical distance from the hydraulic gradient up to any given point within the water passages. The maximum vacuum is therefore not a fixed figure representing the distance from the discharge water surface up to the highest point in the circulating water system, but is a figure which varies with friction in the discharge conduit. If discharge friction is high, the condenser may be set higher or the system discharge lower to utilize maximum permissible siphon recovery. Fig. 4 indicates a typical relationship between the conduit and the gradient.

At sea level theoretical maximum vacuum is about 34 ft of water and vapor pressure for 97 F water temperature is 2.0 ft; therefore, we could theoretically take advantage of a minus 32-ft pressure to reduce pumping head. In practice there are two limitations, however, to how much of this figure we may actually use to advantage. First, if the conduit must be evacuated by vacuum pumps the rate at which commercially available pumps can remove air falls off rapidly at high vacuums, say 28 ft or 29 ft at sea level. Secondly, the rate of air release from the water increases rapidly as the vacuum is increased. There will come a point where air is released faster than it can be removed by vacuum pumps or by the natural pumping action of turbulent water. Air then accumulates and may block off upper condenser tubes, reducing the heat exchanging capacity of the condenser. It may also cause air binding in other sections of the conduit. The author is familiar with one station which successfully maintains a siphon between 29 ft and 30 ft. For design purposes a maximum of 27 ft to 28 ft at sea level is recommended. For plants at higher elevations this siphon must be reduced by the amount of reduction of atmospheric pressure.

For determining probable pump head, the designer must use a reasonable figure for siphon recovery; however, the seal well should be so designed that the operators are not limited to the maximum value of siphon used for the pump design. The permanent crest of the seal well weir, which controls the siphon, should be set low enough so that maximum possible siphon can be recovered at full flow. The operators can then make stop log adjustments to give optimum performance at any flow.

Fig. 4 shows that with a two-pass condenser a substantial reduction in pumping head can be achieved by using top inlet and bottom outlet, as indicated in the dotted lines. The physical top of the outlet water box may be lowered from Point A to Point A^1 (as much as $^1/_2$ the height of the condenser depending upon interior condenser design); the hydraulic gradient remains unchanged. With this arrangement the seal well can then be lowered to take advantage of maximum permissible siphon, thus lowering gradient and pumping head.

Note that the siphon is used only to regain pumping head. It is objectionable in itself and when no pumping head advantage can be gained (as at many water level plants) it should be kept as low as possible to decrease potential air-binding problems.

Air Binding and Conduits Under Vacuum

The greatest potential source of excess head loss is air binding. Air may collect at high points or, often far more serious, water passages may fail to flow full on downward slopes.

Many condenser discharge conduits are designed to operate under a partial vacuum, not only in the immediate vicinity of the condenser, but throughout a large part, if not all, of the conduit. Even the condenser inlet conduits may operate in this manner. It is in these conduits under partial vacuum that serious air-binding problems occur.

Generally where a conduit under vacuum slopes downward, as opposed to a vertical drop, it will not flow full unless air is continuously evacuated; the head loss will be nearly equal to the fall of the pipe (i.e., an open channel flow condition under less than atmospheric pressure). This can be the source of substantial loss. The author has in mind two plants where the excess head losses due to this condition were 15 ft and 19 ft or 35 per cent and 50 per cent above the total head for which the pumps were designed. At these two stations and at several others where the design would lead to a similar condition continuous air evacuation has eliminated the problem.

There are two methods for changing pipe elevation: slope the pipe or drop it vertically. The vertical drop is usually self-priming because of the air-pumping action of the bend turbulence. However, a vertical drop introduces a considerable head loss in two reverse 90 degree bends, and also must be anchored securely even under low head to prevent movement under possible water hammer thrusts. The author usually favors a sloping design for large conduits. The conduit must be tapped for air evacuation not only at the top but along the slope and appropriate air removal equipment provided. Vacuum pumps and water and steam operated air ejectors have been used. These evacuation systems may require power, controls and a source of clean seal water (for vacuum pumps), all of which must be considered when determining the most economical method of making the change in grade.

Within the power plant structure a sloping pipe leaving the condenser may possibly be self-priming if the general turbulence in the pipe is great enough (because of one or more preceding bends); however, if the designer cannot avoid the slope, he should provide air evacuation taps along the slope and be prepared to recommend possible future continuous evacuation.

Collection of air along slopes under pressure does not appear to be serious; small taps at the top and a few feet below the top of the slope can be hand operated to release air on initial start-up. This will speed up the complete filling of the system.

Water Hammer

Generally speaking the possibilities of serious water hammer surges increase with the length of the circulating water system. Surges may occur on pump start-up, on valve closures or following pump tripouts. Simultaneous tripout of all pumps operating on the circulating water system is usually the most serious source of excess surges.

Following tripout, the water leaving the condenser (or other high point on the system) discharges at a faster

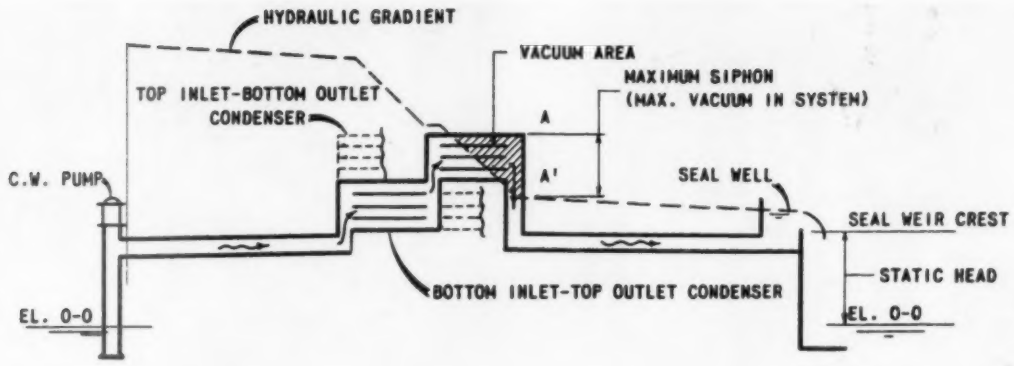


Fig. 4—Use of top inlet and bottom outlet reduces pump head for two-pass condensers

rate than it can be supplied by the rapidly decelerating pumps. The result may be a separation of the water column leaving a vacuous space. When the discharging water exhausts its forward momentum it will reverse its direction of flow and close up this space. At the instant of closure a sharp surge will occur having a magnitude of as much as 100 times the reverse velocity destroyed in feet per second. With discharge lines several thousand feet in length this surge may reach two or three hundred feet of head, many times higher than the normal design head.

Vacuum breakers, air chambers, open manholes and other devices may be used to control water hammer. Fortunately, only a small percentage of stations will require special water hammer treatment, but its consideration in design should never be neglected.

Several actual examples of the development of surges, a review of the elements involved and the methods of surge control are discussed in the author's paper "Water Column Separation in Pump Discharge Lines" which appeared in the August, 1956 *ASME Transactions*. Full tripout tests on the circulating water system of the Ninemile Point Station of the Louisiana Power & Light Company clearly revealed the inherent possibilities of water hammer at a typical large station.

Conclusion

Improvements in many of the design features discussed above have developed from observation of operating circulating water systems. The accuracy of pump head calculations, the hydraulic performance of a given pump intake, air-binding problems and the occurrence of water hammer can only be verified by field observation. The cooperation of system operators is therefore most desirable. Every effort should be made to observe and report on actual system operation, especially where difficult hydraulic problems have been encountered in design.

It is the author's hope that this brief review of the hydraulic features of circulating water system design will not only be of interest to power plant design engineers, but that it will also stimulate discussion leading to our better understanding of the problems involved.

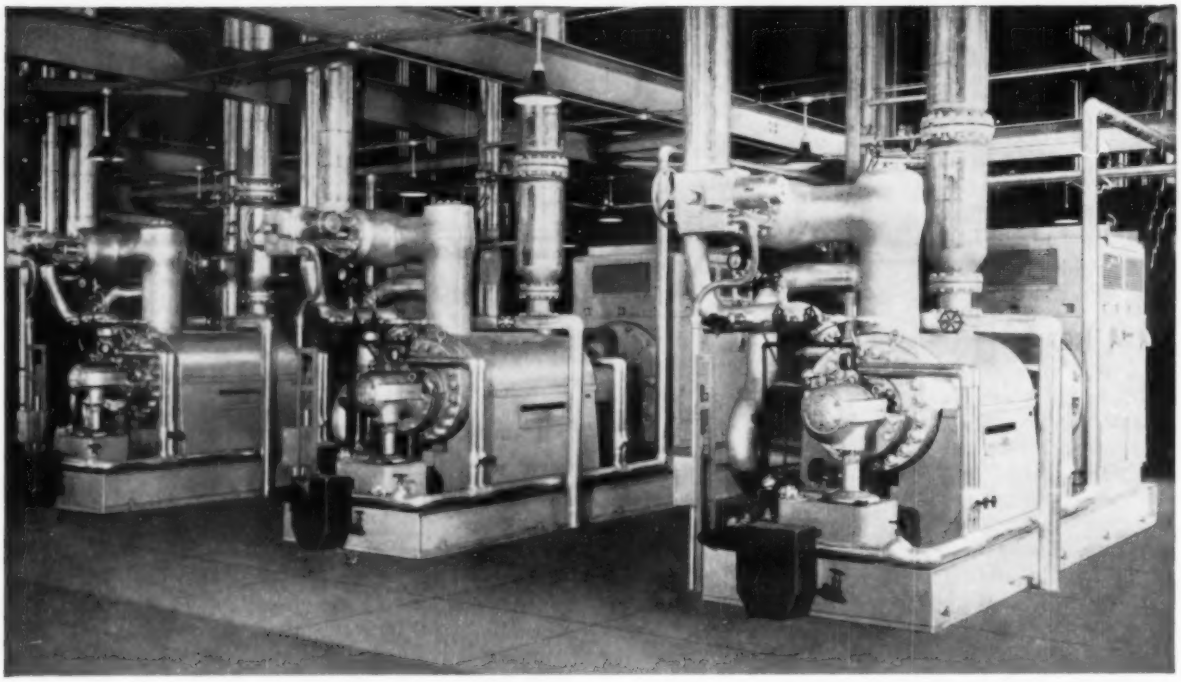
Utility Coal Costs Surveyed

H. B. Lammers, Appalachian Coals, Inc., in his paper before the Annual Meeting at the ASME "Incremental Cost of Burning Coal in Utility Generating Stations," made an analysis of a large number of utility generating stations to determine operating and maintenance costs as related to generation, coal consumption and coal quality and also the incremental cost factors involved.

The analysis included operating and maintenance costs of approximately 75 utility companies and 200 generating stations. Comparisons of operating costs were made between the "old" and the "new" station, as well as for the "modern" station using coals of varying quality.

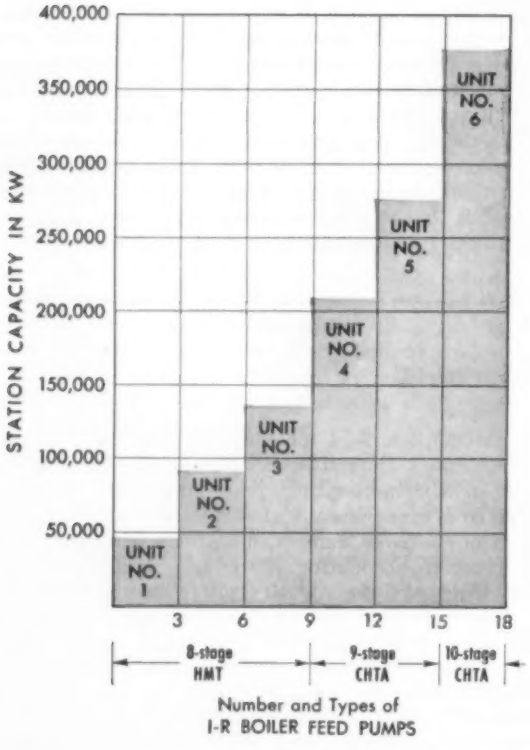
Such operating and maintenance costs referred to were considered to be on a comparable basis for purpose of analysis. This is made possible by the uniform accounting system prescribed for the utility industry by the Federal Power Commission. The possibility of differences in the accounting procedures Mr. Lammers remarked is ever present and should be considered. By reason of the large number of stations reporting, these differences in accounting procedures should exert but little influence on the over-all results shown in this analysis. The values in the analysis and for the stations reporting represent a 3–5 year average, since a single year's record may involve a considerable rearrangement of values if in the course of a year the units are overhauled or if unusual maintenance is encountered.

Mr. Lammers states that while considerable progress has been made in reducing operating and maintenance costs in the boiler plant, further economies can be made.



3 MORE I-R BOILER-FEED PUMPS

serve Unit No. 6 at H. T. Pritchard Generating Station



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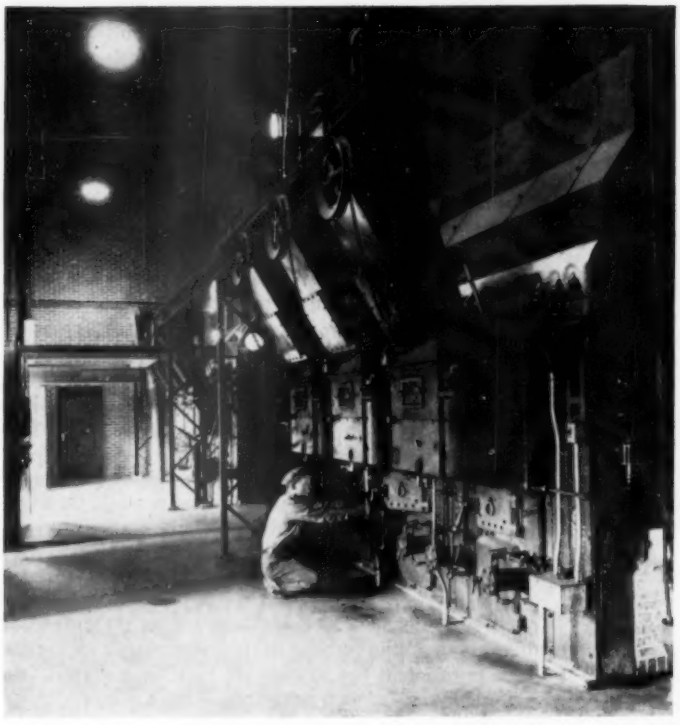

Stoker Operation

The author's opening sentence supplies the reason for publishing a paper on this presumably well-known subject. There are a number of valuable pointers supplied and a description of an operating problem solved by a study of stoker key temperatures.

By LEO J. COHAN

Combustion Engineering, Inc.

THE numerous stoker applications throughout the country would lead one to expect that operating problems were of a minor nature. The simple statement that stoker operating problems arise daily might then appear paradoxical. This is not intended, actually, while it has been said that any method of firing will burn any coal, it cannot be done with equal satisfaction. Thermal energy will be released as long as basic conditions are satisfied, but the degree of refinement is a measure of successful operation.

In an ever changing economy installed equipment may require revised operating techniques. Equipment selected to burn one fuel from one general source may find itself penalized when that fuel supply is no longer available. Design considerations, such as load factor and usage may change, decreasing process loads may readily be supplanted by increasing heating loads. Civic cooperation and the desire we all have to live and work in unpolluted communities have imposed operating problems on many older plants which were not confronted with the air pollution problem until population shifts became a reality.

The purpose of the presentation will not be to discuss specific design considerations or special conditions of stoker applications, because individual analysis of the case in question would have to be considered. It is hoped rather that some general appreciation of the everyday fuel burning problems can be established.

Size Consideration

Once a unit has been selected, what are the controlling factors? Some knowledge of the selection becomes important. In the initial selection of the boiler-stoker equipment it is necessary to establish a realistic load factor. For this reason it is important to talk in terms of lb of steam per hour rather than in boiler horsepower or per cent of rating. The ability to handle wide load variations is by no means license to handle unlimited loads. Carry-over and fly-ash nuisance run rampant when design combustion rates are exceeded.

While naturally in the selection of new equipment maximum load conditions are of prime importance, it must be kept in mind that minimum requirements have to be met. With certain types of stokers the problem of low load operation can create a serious smoke nuisance. One might say it should be a simple matter to extend the theoretical limits of combustion rates to raise the

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minimum rates, but the dictates of efficiency and increased maintenance make this impractical. A realistic approach to sizing of equipment can not be stressed enough. Many plants would be model plants instead of ordinance violators were it possible for them to utilize small units operating within acceptable heat release limits instead of being handicapped by incorrectly sized equipment.

In the existing plants what approach can be used, particularly when plant requirements, over a period of years, have deviated from initial selection standards? One solution is the study of the changes in load factor. For peaks of relatively short duration it is foolish to carry stand-by equipment on the line. It would probably be better to peak with one unit if tests have demonstrated that smoke or fly ash will not constitute a problem. On the low end, maintenance can be greatly reduced if banking or low load operation is kept at a minimum. This may require taking a unit off the line. Banking, or the breaking of a bank, can do untold damage unless carefully considered. This will be supported later by some test data.

Controls

Most plants have some automatic control equipment and instrumentation and therefore it is necessary to discuss their functions.

The initial selection or the revamping of a control system is extremely important to a well-coordinated operation. In the initial selection it is strange that the firing equipment is given prime consideration and the manner of controlling the unit is often given secondary consideration. In many cases the control system required can not be purchased because the projected funds have been exceeded. It is necessary to plan carefully and realize that in modern plants the stoker and controls are in general integral. The performance of one is dependent upon the other.

Several types of controls systems can be utilized effectively in stoker operation.

The positioning system simply adjusts the fuel and air to maintain a constant pressure within predetermined limits. Usually, the actuating impulse is from the main steam header. For a given load change a relative pressure change occurs. This pressure change establishes a definite position for the fuel feed and air flow regulator. This system will offer reasonable approximations of a correct fuel-air ratio as long as the fuel characteristics remain constant.

The advantages of this system are as follows:

1. Simplicity and reliability.
2. More easily maintained by the less skillful operator.
3. Low initial cost.

Certain basic disadvantages cannot be ignored and can be the source of many daily plant problems if not carefully understood.

Namely:

1. Readjustment of linkage and the necessary tests to establish this becomes necessary when major coal changes take place.
2. Efficient operation throughout a wide load range is dependent upon the experience and ingenuity of the personnel placing the system in initial operation and equally dependent on those maintaining it.

As can be seen from the aforementioned where efficiency is desired or where plant load has changed from, essentially, a base load plant to one with wide output range another type of control is desirable and this would lead to a brief discussion of the metering or proportioning system.

In this system the gas or air flow is metered across the boiler or duct-work and the draft loss, being a function of flow, is balanced across an actuator working in conjunction with the steam pressure or flow component. This proportions the rate of coal feed against air flow in accordance with previously made calibrations.

As can be seen the advantages this system offers are as follows:

1. Higher average efficiencies are maintained throughout average load ranges.
2. More responsive action over wider load ranges without overriding.

With both the metering and positioning systems some means of controlling furnace draft is necessary. This can be incorporated in the system or may be accomplished by independent furnace draft regulation.

Instrumentation cannot be overlooked since it provides a reasonable guide to the routine adjustment of controls. In everyday operation visual indication of the furnace and boiler conditions is extremely helpful to the operators. Draft indicators are important instruments. Steam flow indicators incorporating air flow indication is a helpful firing guide. Smoke indicators and CO_2 or O_2 recorders assist in maintaining high operating standards.

One point of caution should be stressed. No system can duplicate intelligent thinking and reasoning on the part of the operator. No system can replace an operator without substituting an expert control man well-versed in operation. No system can be any better than either of these men. A neglected system will only reward the plant with high maintenance, low efficiencies and other attendant problems.

Coal and Ash Handling Equipment

When one considers how dependent the stoker equipment is on allied equipment one cannot ignore the importance of this equipment in new plant selection, expansion or maintenance in existing plants.

Sufficient inside storage should be provided to insure a substantial supply of dry fuel and the necessary insurance in the event of mechanical failure of the external coal conveying equipment.

To avoid serious segregation, the manner of loading the bunker should be studied. While swing spouts or a weight larry provide excellent means for delivering the fuel uniformly to hoppers, serious segregation can be avoided by the techniques in practice for loading the bunkers.

Ash pits should provide sufficient storage capacity to provide maintenance time or ash conveying equipment. Pits should be sealed to minimize leakage to the furnace. Periodic preventative maintenance is related to high

operating standards. Furnace conditions are generally disrupted during cleaning periods and therefore cleaning should be accomplished in a minimum period of time. Boiler air-flow controls should be put on manual during cleaning periods, if it is at all possible, to prevent reduced air flow through the grate surface.

Coal Selection

Fuel selection for the particular equipment in question cannot be considered secondary. While all coal is mined on a ton basis it is generally purchased on a million Btu basis. Each type of stoker will perform best with the fuel selection that considers all factors including delivered price.

Ash Fusion Temperature is generally given consideration in specifications, whereas Free Swelling Index for bituminous coals is often neglected. Eastern bituminous coals were not considered suitable for progressive burning stokers not so many years back. This no longer is true. It would be erroneous to maintain that all Eastern coals are suitable for traveling grate stokers but many are, with proper preparation and correct size consist. The Free Swelling Index then becomes important and should be part of the specifications.

With spreader stoker operation coal sizing is a more important characteristic than many of the coals' chemical properties. Many of us have made the mistake of specifying the sizing in accordance with manufacturers recommendations without fully realizing that the specified was to be that required at the stoker, not the mine, siding or overhead bunker. It is necessary to modify initial specifications, to adjust for the friable characteristics or degradation in storage or handling, do so by all means. Constant surveillance is required to insure uniform and efficient performance.

When considering the commercial sizes of anthracite, the limits are more closely defined. Top and bottom limits are accepted but little attention is given to the percentage of oversize or superfines as long as general tolerances are met. Many properties or characteristics do not show up in the routine analysis and consideration has to be given to special techniques when circumstances dictate.

To better illustrate this let me cite the experience of a rather large anthracite consumer. For several years their supply was from one source of excellent quality. Unfortunately this source became less available and other sources were procured. The normal specifications were standard and checked frequently, but a predominance of undersize coal was not uncommon. Rejection of this was impractical. Under certain conditions, boiler capacity fell off as much as 35%. Observation of the fuel bed revealed large mounds of unburned and partially ignited fuel with resultant high ash pit losses. It was apparent that air penetration was inadequate. Simple tests were devised to determine what was taking place and it soon became evident that the superfines plus other factors such as clay and silicates resulted in a fuel bed impervious to air flow.

The test procedure to determine this was not complicated. Essentially it consisted of baking standard samples at approximately 300 F for about one hour and the surface resistance to penetration measured by incrementally loading a rod suspended over the sample in a jig. By further baking it was determined that samples once penetrated or agitated would not again cake.

Air flow measurements or the resistance to flow were also measured on standard samples.

The result was, that a mechanical means of agitating the fuel bed in the furnace was considered. It took the form of a round steel bar across the width of the stoker, resting on the grate. This bar was tied to the front hopper by means of tie rods and clamps which would permit movement of the bar away from the front or rear of the stoker until the optimum point in the furnace could be established. The fuel bed had to hurdle the bar in its travel to the rear and it was so agitated that the air readily passed through over the burning zones.

With good coals no increased capacity was evident but the breaker bar was most beneficial in burning the undersize clay laden coals.

Ash, as a constituent in coal, is generally considered a necessary evil. It is expensive to all parties. When a manufacturer specifies "Coal no less favorable than," what interpretation do you apply to ash? Naturally the purchaser thinks in terms of ash in low values, but a reasonable percentage of ash is necessary to keep grate maintenance in line with unit efficiency. The current design trends tend to stress the advantages of heat recovery equipment such as air heaters, economizers or their combinations. At the same time increased mechanization at the mine and modern washing or cleaning procedures have reduced the ash content of coal "as fired." Somewhere between these two limits can be found the sound economic balance.

Stoker Maintenance

Stoker maintenance is effected by many factors such as: ash content, control systems, segregation of fuel, load factor and operating techniques.

Of course, there is the mechanical type of maintenance which is handled on a normal routine basis. There can be no substitute for good design, erection, and workmanship. Replacement of parts with care and consideration is important. If a piece or part looks like it might last and you are anticipating a reasonable usage factor, replace it at the first opportunity. Do not compromise immediate economics with prolonged outages when load carrying capacities can be critical. Inventory of more frequently used parts is essential. Deliveries can not always be made as quickly as they may be required. A good preventative maintenance program pays dividends.

The question arises as to how do the other problems manifest themselves, and what can be done to correct them. Generally many stoker operating problems become apparent when key growth or key burning occur. This situation may start in a few isolated sections but soon can become malignant unless the cause of the problem is known and immediately isolated.

We have all heard explanations as to why a grate surface burns. Insufficient air is probably the most common explanation and all too frequently incorrect. The answer is quite simple, keys burn because they get too hot. Let us explore this further in the interest of isolating cause from effect.

Manufacturers, clients and research organizations have developed some techniques which can be used to determine the cause of many grate burning problems.

The use of Templistik or similar paints to determine grate temperatures can be used. This method consists of marking or painting the grate surface with a substance that will change color or disappear at a stipulated temperature. The results obtained from this method can give you maximum temperatures that the surface is subjected to, but unfortunately there is no way of knowing where or when the temperature peaks occurred and hence limited basis for study. It is however, a rather simple check and may be used in conjunction with metallurgical analyses when improper material selection or quality is suspected.

A more informative method is one in which thermocouples are actually peened or wedged into individual test keys or grate areas. On a traveling grate their progress in distance and time can be plotted against temperature. All other pertinent factors or known factors should be recorded.

Fig. 1 illustrates how the thermocouple may be attached to the test key. It should be noted that light gage wire should be used so that the lead wire can be fed through the machine, under or adjacent, to the grate supporting surface. The use of multi-point switches make it possible to utilize more than one set of test keys almost simultaneously. It may be realized that specific techniques must be developed for various types of machines since the design characteristics may differ.

The following illustrates how the procedure may be put to practical exploratory use and has been taken from actual field test data.

The case in question was one in which severe key burning and warping of keys was taking place on a small industrial unit burning anthracite on a traveling grate stoker.

The installation consisted of two units. Both were operated when the load was heavy and one was banked during light load periods. Banking occurred daily.

The fires in general appeared good and casual observation did not reveal the cause of key destruction.

Thermocouples were peened into several test keys and the temperatures of the grates recorded.

1. Under normal conditions.
2. Under banking conditions.

Fig. 2 shows the temperature of 3 keys during the time a unit was being banked. The keys were put on the stoker and run into the furnace, then the stoker was stopped and banking started. No. 1 key was about $13^1/_2$ ft. from the base line and was 40 in. ahead of No. 2 key. No. 3 was 24 in. in back of No. 2 key. Temperature readings were recorded at 10 minute intervals from 1:40 until 2:50 p.m. At 2:50 the test was terminated because the No. 3 key had begun to cool.

The fire reached well into the 5th compartment when banking was started. In order to hasten the burning out of the fuel bed the operator raked the fires. The insulating ash bed protecting the grate was thus disturbed and the hot fuel bed came in contact with the test keys, raising their temperature high enough to cause key burning. At 1:50 p.m. the temperature of No. 1 key was 980 F, immediately thereafter the fire was worked with the bar and at 2:00 p.m. the temperature had risen to 1315 F and 10 minutes later it was at 1415 F, falling off ten minutes later as the fire burned out to 405 F. It is apparent that the key was at an unsafe temperature for more than 20 minutes.

Key No. 2 reached a maximum of 1408 F but its ex-

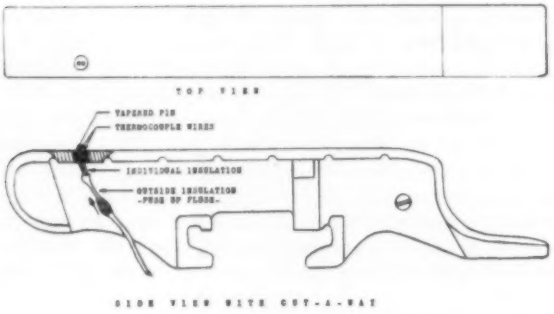


Fig. 1.—Plan view and elevation of a typical stoker key showing the point at which a thermocouple is connected

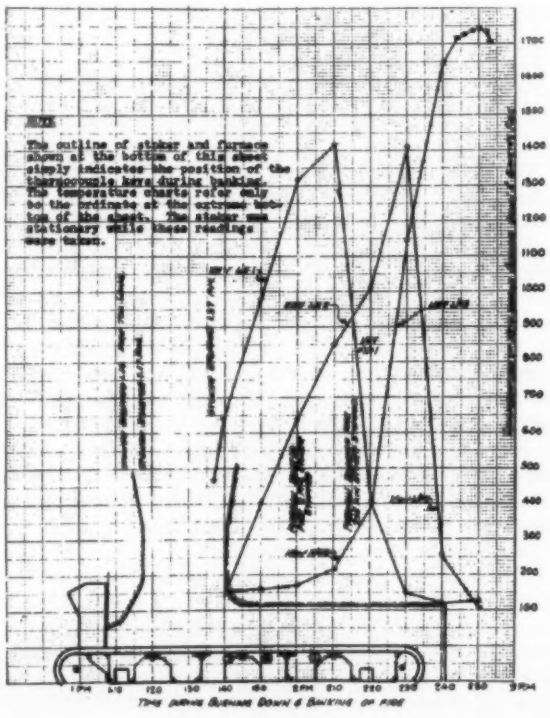


Fig. 2—The temperature of three keys such as in Fig. 1 are shown for a banking period. Chart gives further explanation

posure time was only 14 minutes, a relatively short time.

As the fuel bed over No. 3 key burned down and was agitated by raking the temperature rose to a maximum of 1743 F and remained there for more than one half hour.

In tests conducted under normal operating conditions the maximum temperature observed was 1192 F and this peak was almost instantaneous.

As a result of the test information a re-education program was started with the plant personnel and the detrimental operating practices discontinued.

In any analysis of this type care must be exercised to analyze the data on a time-temperature basis. Instantaneous peaks may not be as dangerous as sustained soaking heats. For un-alloyed cast iron grate keys, peaks of 1000 F or higher can be reached if not sustained.

Similar tests can be used as a guide to good firing practices since they reveal many factors such as:

Ignition point.
Effects of segregation.
Effects of ash content for comparison.
Fuel distribution problems.
Draft considerations.

General

Very little has been said relative to boiler design and its effect on stoker operation because, to a large extent, this is a fixed factor. Boiler cleanliness and setting or casing leakage are variables which influence overall operation and are under the control of the operators.

In general, a well-operated stoker is found in a well-operated boiler plant or power house. Constant attention to the many details encountered in everyday operation lead to continuity of service and high equipment availability.

Most manufacturers maintain technical staffs to assist their clients. They, of course, do not have the intimate knowledge of your plant or its operating problems, but they do know their own equipment and, in most cases more important, they have daily contact with many plants with diversified processes and problems. This varied experience factor can prove invaluable.

Conclusions

Successful stoker operation can be achieved by:

1. The knowledge of the design limitations of the operating equipment and the willingness to take advantage of the flexibility of the equipment within the limits of good operating practice.
2. The constant surveillance of fuel selection and specifications.
3. A good organized preventative maintenance program.
4. Revision of operating procedures or practices when objective test data so dictates.
5. Cooperative and active participation in groups representing manufacturers, fuel suppliers, research institutes, operators, state and municipal officials.

A Chief Engineer's Lament

Now I am an old timer,
In this power station game,
And this automation scares me,
Though to some it has brought fame.

In days of yore you'd operate,
With just plain brains and brawn,
But now you've automation,
The good old days are gone.

Your boilers now have cut backs,
That some say, are quite fine,
But if a pilot torch should fail,
You're quickly off the line.

Your operators are well trained,
And get the highest pay,
Automation makes them helpless,
They have no more to say.

The latest gadget that we've got,
Is a sewerage tank alarm,
If the syphon plugs, the levels high,
Don't fear, it you won't harm.

Now automation has its place,
In industry today,
But please don't overdo it
This is what I want to say.

Leave to the operator, friend,
A chore once in a while,
Don't treat us all as morons,
Let us regain that smile,

Of confidence and pride again,
In each job that we take,
We like alarms and signals,
But let us operate.

So don't shut down our boilers,
With every little puff
Our job is making steam you know,
So let us make the stuff.

Anonymous

ASME Annual Meeting Highlights—II

Last month COMBUSTION reported on the Annual Meeting of the ASME held at the Hotel Statler and the Hotel Sheraton-McAlpin in New York City the week of December 1–6. The following papers are abstracts from that same meeting which we did not carry before because of space limitations.

Water Treatment

R. G. Dalbke and **J. F. Wilkes,** Dearborn Chemical Co., collaborated in presenting the paper "The Effect of Mechanical Factors on Condensate-System Corrosion." Oxygen and carbon dioxide dissolved in steam condensate are recognized as the major chemical causes of condensate-system corrosion.

However, mechanical and physical factors of design, installation and operation also contribute significantly to return-line corrosion problems. A well-planned corrosion-abatement program must include, the authors believe, corrective action for mechanical deficiencies, in addition to properly selected chemical-treatment methods which have been described previously.

Oxygen and carbon dioxide in steam are minimized by proper feedwater pretreatment, but may enter condensate-return systems through vents, air leaks, or raw-water injection. Volatile amines neutralize carbonic acid in condensate; filming inhibitors offer protection against both oxygen and carbon acid attack. Inhibitor performance can be nullified by carryover, oil contamination, or steam collapse, which disrupt protective films. Unless steam traps and drains are sized and installed properly, sources of air inleakage eliminated, and other mechanical problems corrected, the corrosion-abatement program must fail. This paper described operating problems contributing to condensate-system corrosion and offered practical solutions.

F. J. Enright, Allis-Chalmers Mfg. Co., gave as his paper "The Development of An Experimental Laboratory for Performance Tests of Steam-Turbine Blading." As Mr. Enright explains, despite the high level of performance attained in the modern steam turbine, the search for improvements cannot be relaxed. There are still many basic problems concerning the fluid mechanics of turbine blading which are not completely understood, and continuous research and development work on blading performance are necessary to solve these problems in an effort to increase turbine efficiencies.

In 1955, a decision was made at the author's company to supplement the existing test facilities with a modern experimental turbine laboratory. An important consideration was the selection of a working fluid for the turbine. Air was chosen over steam for the following reasons:

(1) By providing the laboratory with its own air-supply system, it was made independent of other facilities except for a source of electrical power. A steam supply and condensing system within the installation area would have made laboratory design and operation more complicated.

(2) Because air very nearly obeys the perfect gas laws at atmospheric pressures and moderate temperatures, the calculation of test results is easier than for steam.

(3) Air does not present the condensation problems that would occur with steam. Drains are not required on the equipment, and manometer connections can be made simpler.

The experimental turbine laboratory described in this paper was costly in terms of both engineering time and money. The investment in such a facility, the author states, is justified, however, when it is realized that improvements obtained from laboratory tests will be incorporated in the design of new steam turbines to continue the trend toward more efficient generation of power.

Steam from the boiling water reactor of the Dresden Nuclear Power Station will enter the turbine at 869 psia and 525 F with $^1/_2$ per cent moisture and with oxygen concentration higher than normal in power-plant practice. Hence, **H. A. Cataldi, C. F. Cheng** and **V. S. Musick,** General Electric Co., were assigned to the "Investigation of Erosion and Corrosion of Turbine Materials in Wet Oxygenated Steam." Their paper discusses a series of preliminary laboratory tests evaluating the resistance of various materials for turbines and related components to erosion (impact, washing, wire-drawing) and corrosion (weight loss, pitting depths, crevice, and galvanic attack) in wet, oxygenated steam. Materials tested included carbon and low-alloy steels and cast iron, austenitic and ferritic stainless steels, Monel, cupro-

Colonel Davies, left, retiring secretary of the ASME is shown congratulating his successor, O. B. Schier, right.

nickels, leaded bronze, Stellite, and Ductile Ni-Resist No. 3. It is concluded that, with proper design, conventional materials may be used in the Dresden turbine except in a few critical areas.

(1) On the basis of this preliminary evaluation, erosion and corrosion of a turbine in a boiling water nuclear power system can be maintained within tolerable limits with proper design and the selection of special materials for critical areas. This evaluation is being supplemented by continuing laboratory tests, and by the operation of a 5000-kw turbine directly connected to a 10,000-kw boiling water reactor at the Vallecitos Atomic Laboratory (Atomic Power Equipment Department).

(2) In wet steam with low (0.05 ppm) and high (100 ppm) oxygen, stainless steels, Monel, and Stellite 6 were most resistant to "wire drawing" erosion. Ductile Ni-Resist 3, low nickel steels, and low chromium steels were better than low molybdenum and carbon steels; plain cast iron was the least resistant material tested.

(3) In wet steam at pH 7 and 430 F, there was no effect of oxygen on erosion in tests with high and low oxygen concentrations, except for BTH leaded bronze. With low oxygen, BTH leaded bronze resembled low chromium steel in erosion; with high oxygen, it resembled plain cast iron.

(4) In wet steam at 300–430 F, and pH 7, with low and high oxygen, stainless steel, Stellite No. 1, and Ductile Ni-Resist No. 3 were most resistant to corrosion. Monel and low-alloy steels are superior to carbon steel. BTH leaded bronze was the least resistant material tested. At lower temperatures (300–400 F) and low oxygen, the cupronickels were comparable to the most resistant materials; at high oxygen, they very rapidly approached the extreme corrosion rate of BTH leaded bronze.

(5) At 300—430 F, pH 7, increasing the oxygen level from low to high increased the corrosion rate of all materials tested except stainless steel. In the case of carbon steel, this effect of oxygen on corrosion diminished rapidly with increasing temperature. With the cupronickels, the effect of oxygen was much more severe at 400 F than at 300 F.

(6) Corrosion rates of all the materials tested, at high and low oxygen, increased with temperature, the logarithm of the corrosion rates varying approximately linearly with the reciprocal of the absolute temperature.

(7) At 430 F with high oxygen, there was no intergranular corrosion of sensitized types 304 and 304L stainless steel specimens in 1000 hours, nor were there any cracks around heavily stamped crosses.

(8) With low oxygen, there was no pitting observed except with carbon steel, where the effect was minor. With high oxygen, all materials pitted especially at crevices. Stainless steel and Stellite No. 1 were most resistant. Monel, cupronickel, and BTH leaded bronze were better than low-alloy steel. Carbon steel pitted most severely.

(9) In autoclave tests in steam-water-oxygen mixtures (545 F, 1015 psia, 50 and 100 ppm O_2), run for 6 and 10 weeks, the rates of corrosion decreased with time. The maximum depth of pitting, however, did not increase significantly.

(10) The order of resistance, as measured by the maximum depth of pitting was the same as for resistance to general corrosion. There was less difference in the maximum pitting depths among the ferrous alloys tested than there was in the corresponding weight losses. This reflects the greater number of pits in the least resistant alloys.

(11) There were no significant galvanic or crevice effects in the autoclave tests. Naturally formed deposits of iron oxides were more effective in promoting pitting on all classes of steel tested than were artificial 0.002 in. crevices.

(12) Cast iron and low-carbon steel were subject to occasional very deep pits in the autoclave tests. These may be related to inclusions and/or pin-hole porosity.

S. F. Whirl, Duquesne Light Co., submitted the paper "Diet for Boiler Allergies." Any successful method of boiler water treatment must consider the dilute boiler water with respect to its ultimate effect on being concentrated. Recognition of this dual nature of boiler water has not only forced changes in the principle of treatment formulation, but also has placed new emphasis on the control of boiler water conditions. What simpler remedial measure could be taken to control the boiler diet than to exclude all caustic from the boiler water? The Coordinated Phosphate-pH Control Method does this.

A graph is the basis of control. It was formulated by determining the pH of a series of solutions prepared with reagent-grade trisodium phosphate and pure water. By plotting the pH value and the PO_4 concentration of the boiler water on this graph, it can be ascertained readily whether or not the boiler water contains free sodium hydroxide. A point which falls on the curve indicates that all phosphate exists as trisodium phosphate.

A point which falls below the curve shows the presence of acid-phosphate salts; a point in the region above the curve is evidence that free caustic is present. Berl and van Taack measuring the attack of water (1418 psi) on iron filings over an extensive pH range, established that steel is best protected in the region of pH 11. It is the practice of the Duquesne Light Co. to maintain a boiler water pH of 10.7 to 10.8.

It is felt that sulfite has a definite place in boiler-water treatment, but that it should be used with good judgment. It should be fed continuously, directly to the boiler in low concentrations, maintaining about 1 to 2 ppm in the boiler water. It should never be fed into the system ahead of the attemperator water take-off point. It should not be fed ahead of the deaerator. It should never be fed to low pH boiler water. Where sulfite treatment is used, a boiler water pH of at least 10.7 should be maintained.

Dr. Whirl stated that in many respects hydrazine is an ideal chemical for combatting corrosion throughout the system. It reacts with dissolved oxygen, although at a slower rate than desired. It does not leave a solid deposit and therefore can be used in spray attemperation water. This permits its injection at the hotwell, giving some protection through the entire condensate cycle. The author has been unable to detect hydrazine in boiler steam even when adding more than twice the stoichiometric requirement. Further study and experience are needed to fully establish its merits.

Volatile alkalizing amines effectively neutralize acid anhydrides such as carbon dioxide and sulfur dioxide in the condensate. A pH value of about 9 is used.

The Fuels Division assisted by the Research Committee on Corrosion and Deposits, the Research Committee on Furnace Performance and the Committee on Air Pollution Controls presented a wide range of papers covering equipment, operating practices and theory.

F. C. Messaros and **F. C. Belsak,** American Engineering Co., supplied a paper on "New Concepts in Stoker Design." The company with which the authors are associated undertook an extensive research and development program to find a type of stoker based on a new principle of operation but still burning the fuel entirely on grates.

During the early stages of this program, attention was given to the vibration principle of operation. Subsequently a full-size grate model was set up in the company's laboratory for test purposes. Following a number of experiments performed on this unit, our attention was directed toward a similar fuel-burning device developed by L. &. C. Steinmuller already introduced and in use in Germany. Owing to the success achieved with our basic design, the company believed it worth while to make an extensive investigation of this German unit. The features which particularly attracted them to this unit were its constructional simplicity with amazingly few actual moving parts and its generous grate area which would contribute to the solution of the air-pollution problem at all loads.

The water-cooled grate was another feature which appealed to the authors' company in view of their previous successful experience with the water-cooled Taylor stoker. The ease with which the fuel bed was controlled under actual operating conditions and the resultant auto-compacting of the bed confirmed their earlier laboratory studies that the vibrating principle was a definite asset to the combustion process.

This paper relates the development of the authors' first vibrating-type industrial stoker in this country, together with a report of observations and performance obtained from tests on units now in operation both here and abroad. The first stoker unit of this type built in the U.S.A. was installed at Bituminous Coal Research, Inc., Columbus, Ohio, for use in its package steam-generator-development program. The paper, by Mr. Kock, discusses experience with this unit.

The paper selected as a follow-up to the above, "Problems in the Development of the BCR Automatic Coal-Fired Packaged Steam Generator" was offered by **Paul O. Kock,** Bituminous Coal Research, Inc. Aside from a constantly increasing differential between the costs of bituminous coal and the fluid fuels, the gas- and oil-fired packaged steam generators have some limitations which the author believes eventually set the stage for the development of the coal-fired counterpart. Probably foremost among these limitations is the ever-present danger of explosion from leaking fuel lines, particularly in the furnace. Elaborate and highly sensitive electronic flame-failure and ignition-monitoring controls which are essential, have proved notoriously expensive and delicate instruments.

The fundamental requirements for the development of a coal-fired automatic packaged steam generator were set down at the beginning of the project.

(1) Provide a boiler-burner combination which could burn a variety of bituminous coals efficiently and could accommodate a varying load. The burner must have a quick heat-release response to sudden load increases and give economical operation over a five-to-one turndown.

(2) Design an automatic ash-removal mechanism to be an integral part of the boiler-burner combination, to provide for accumulating the refuse discharged by the grate. This mechanism must automatically convey the refuse to a storage bin, containers or other conveyor.

(3) Develop a control system that would automatically coordinate the functions of the forced-draft and induced-draft fans, stoker, ash conveyor and all safety limits so that the steam generator would efficiently carry wide and sudden load changes. Also the control system, in response to an external signal, must be capable of cutting the generator out of service, maintain a nonsteaming banked fire for indefinite periods of time, and again in response to a signal bring the generator up to operating conditions. All of these functions must be without manual attention.

(4) The complete generator must have maximum compactness. The design of all of the components, boiler, burner, fans, ash conveyor, and controls, must permit factory assembling and testing of the assembled combination before the package is shipped to the user.

(5) The complete generator must include such equipment as would assure an economically feasible product. The selling price must be competitive with other fuels.

The author describes in considerable detail the studies and the evolution of each of the major elements comprising the final laboratory model.

Excellent operation with prompt response to sudden and wide load changes was reported with all of the coals tested except one. All were fired as modified stoker size containing from 15 to 35 per cent of fines ($^1/_4$ in. $\times$ 0), and having surface moistures varying between 2 and 8 per cent. The range of free swelling indices was from 3 to 10, and the ash-softening temperatures varied from 2000 to 2700 F. The new equipment showed no sensitivity to any of the coal characteristics except to the caking or agglomerating behavior. One of the coals tested was classified as being extremely highly caking, and although it gave good results when the equipment was under load and also during holdfire, automatic starting was unreliable. A caked condition of the banked fire would develop on holdfire periods of longer than 8 hours. When the starting cycle would come on, this caked condition would definitely retard re-establishment of ignition in the entry zone of the fuel bed. This condition could be alleviated by maintaining a more active fire during holdfire, but because of the high heat content of this coal, even a slightly higher burning rate would result in generating steam. This is one of the problems still to be solved.

Other problems in the development work remain to be investigated, and it is expected that there are still some to be encountered. Also, tests are planned to determine such values of design interest as the circulation conditions through the various tubes of the new boiler, particularly the rear arch support tubes and the grate tubes. Accurate grate-surface temperatures are to be determined and the heat-absorption rate of the grate circulating water should be investigated more thoroughly to enable a more complete appraisal.

R. M. Schahfer, F. H. Strout, Northern Indiana Public Service Co., and **G. W. Land,** Traux-Traer Coal Co., explained the "Application of Bonus-Penalty Method to Coals Being Purchased or Evaluated." Any method of controlling the overall cost of coal should cover all items of expense connected with converting the heat energy in the coal to steam produced for the turbine.

The authors feel they have developed a practical method for maintaining the net cost of the coal purchased at the value originally quoted, and for comparing the real or net value of coals submitted for purchase. This paper outlines the method used for adjustments to the price paid for coal and cost comparisons of coal to be purchased; presents the method of application now in use; and gives illustrations of the derivation of the values used in the application.

Price per ton or price per million Btu as received, with no adjustments being made for the respective quantities of moisture, ash, and sulfur in the coal does not reflect the net value to the consumer. True value to the consumer increases with increased Btu per pound and decreases with increased amounts of moisture, ash, and sulfur present in the coal. Handling charges within the plant, including power costs and maintenance, heat losses in the boiler or steam generator, and power replacement costs resulting from decreased boiler availability or capacity are items which must be considered in determing the relative or true value of coal.

If adjustments to the cost of coal can be made to reflect properly the increased or decreased costs within the plant, resulting from more or less moisture, ash, and sulfur, the true value of the coal may be obtained. Such adjustments may be applied as a bonus for better coal or a penalty for poorer coal than that guaranteed. Hence the name "bonus-penalty method." It follows that the same adjustments may be used to obtain true comparative values when several coals are submitted.

Costs affected by variations in coal quality may be derived into three general classes as follows:

(*a*) Cost of handling coal and ash, including labor, maintenance, mechanical, and power costs.

(*b*) Changes in heat losses resulting from variations in quality of coal fired.

(*c*) Cost of replacement power resulting from boiler outage time for maintenance, or reduced capacity because of combustion difficulties.

After considerable study, a decision was made to relate these costs to loss or gain in the Btu value of coal, and to use the Btu loss or gain as a correction to the as-received Btu per pound.

The principal advantage of converting all incremental costs to terms of Btu adjustments per per cent variation of moisture, ash, and sulfur is illustrated by examples of the method used.

Calculation of the Btu values used for adjustments, based on the authors' experience, are described in brief detail for each cost affected by variations in quality.

D. R. Anderson and **F. P. Manlik,** National Aluminate Corp., offered a paper on "Sulfuric-Acid Corrosion in Oil-Fired Boilers—Studies on Sulfur-Trioxide Formation." Experimental studies on economizer and air-heater corrosion resulting from the formation of sulfuric acid in residual-oil-fired boilers are described. Factors controlling the oxidation of sulfur dioxide to sulfur trioxide have been investigated in a small experimental boiler. The fuel used was a distillated oil to which synthetic compounds were added to simulate the sulfur and metallic components commonly found in residual oils. The sulfur-trioxide content of the flue gases was determined indirectly by measuring the corrosion of and sulfate deposition on a steel specimen maintained at a controlled temperature. In an initially clean boiler, approximately equal quantities of sulfur trioxide formed in the flame, furnace, and convection sections, while less formed in the economizer-air heater section. Nickel, iron, sodium, and vanadium in the fuel each lessened the corrosion normally experienced by the test specimen, the magnitude of the effect increasing in the order given. Deposits of these metallic fuel-ash components in the boiler had a relatively small effect on the corrosion of the test specimen. Only the iron deposits indicated significant catalytic activity for the oxidation of sulfur dioxide to sulfur trioxide. Combinations of sodium and vanadium in the fuel were found to lessen corrosion in an initially clean furnace but boiler deposits from certain combinations of these elements were found to increase corrosion substantially. This catalytic effect is predominant over extended periods of time.

The subject of "Handling Coal on the Public Service System" was taken up by **R. A. Baker,** Public Service Electric & Gas Co. An opportunity to exploit certain of the more recent ideas came in 1954 with the design of No. 7 unit for the author's Burlington Generating Station. While this project was an addition to an existing station, there was no unused bunker available for use. In this new concept, the enclosed bunker is replaced by a large active coal pile located in the center of the existing outdoor long-term storage pile over three new ground-level reclaim hoppers which were built into a reinforced concrete structure. These storage pile hoppers feed a series of conveyor belts which are controlled from level in the 4-hr bins immediately above the pulverizer feeders, as in the earlier installations; and a single belt fills the area immediately above the storage-pile reclaim hoppers, just as was done in the case of bunkers. However, the walls of this outdoor bunker consist of three connecting circular rings of coal, which are compacted by tractor and located the proper distance from the hoppers, so that a free-flowing volume of loose coal is located above the hoppers within the confines of the compacted area. External to the rings is the long-term storage pile made with bulldozer, tractor, and perhaps, in long hauls, with carryalls attached to the tractors. When the supply of river-borne coal is low, tractors bulldoze a sufficient supply into the loose pile over the hoppers, but, of course, under normal river-borne supply, the loose active pile is maintained daily by hoisting from barges.

Three belt feeders located one each under each storage pile determine the rate of flow of coal through the automatic conveyor system and, since the nominal rating of the system is 100 tons per hr, only one feeder is required at any one time for No. 7 unit. The selection of the feeder is made by the control-room operator.

Each feeder conveyor has a "no-coal" device which actuates the vibrator on the rubber-mounted, stainless-steel hopper, from which the feeder conveyor receives coal. The "no-coal" device is interlocked with the feeder conveyor through a centrifugal switch so that the vibrator will not operate unless the conveyor is running and the hopper outlet gate is open.

Reader Comments on Cooling Towers and Coal Bins

DEAR EDITOR

I have just finished reading two excellent articles in your November 1957 issue, No. 5, Vol. 29. While I have found both articles very enlightening and interesting, I would also like to comment on certain points which, I believe, require clarification.

My comments are written separately for these two articles, and your kind cooperation in publishing them would certainly be appreciated.

Comments on *Selection and Application of Cooling Towers in Steam Electric Stations*, by E. E. Goitein.

Concerning hyperbolically shaped, atmospheric cooling towers, the writer believes that there are two reasons why such towers have not, as yet, been built in this country.

One of the reasons is that, unlike conventional mechanical draft towers, such installations are, in large part, more in the line of the structural than mechanical engineer. The design of thin shell high towers, together with their precast posts and beams, for fill and pipe supports, and the use of thin transite sheets for fill, calls for a coordinated structural design of advanced degree. If one considers the financial responsibility for the design, construction and performance of such rather expensive towers, one realizes that the past experiences of the European designers are required for such towers. It is interesting to note that the HAMON Company of Belgium and France has recently organized their American office in order to offer such towers to the American industry.

The second reason why hyperbolically shaped atmospheric towers have not been built is that the latent advantages of such permanent reinforced concrete towers have not been presented to the interested public. A thorough analysis including not only initial costs, but the numerous economic and operational advantages of the hyperbolic towers, definitely indicates the desirability of such towers. The following list includes some, but not all, of the advantages of the hyperbolic towers.

	Conventional induced draft	Hyperbolic atmospheric
Replacement of main structure of tower	six to twelve years	permanent
Replacement of fill	two to ten years	permanent
Replacement of mechanical parts, shafts, bearings, fuses, switches, etc.	two to six years	none
Material to rot or deteriorate	about 80%	none
Maintenance	substantial & constant	none
Power consumption for fans	substantial & constant	none
Electric wiring system	considerable	none
Pumping head	average	few feet lower
Vibration due to resonance of fans and tower	considerable	none
Fire hazard during off-season	very great	none
Hazard of mist or fog; danger in the proximity of roads and streets	great	none
Hazard of frozen spray on nearby equipment	great	none
Resistance to high winds, hurricanes, tornadoes, earthquakes, etc.	mediocre	very great
Fungus development	considerable	very small or nil
Insurance premiums	high	very low

Comments on *Flow of Coal in Bins*, by F. D. Cooper and J. R. Garvey

The writer wishes to take issue to the statement that only rule-of-thumb methods are available for the design of bins. The *Transactions* of the American Society of Civil Engineers, Vol. 117 (1952), includes the writer's paper entitled *Design of Large Coal Bunkers*. This paper, which was prepared while the writer was then employed as a design engineer by Sargent & Lundy, contained formulas for shallow and deep bins, bunker walls were analyzed as flexible plates and unbalanced forces due to asymmetry also were analyzed. The problem of inward pull was presented, continuity analysis introduced, etc.

Further reference is made to the "American Civil Engineering Practice," Vol. III (Wiley), Section 32, "Reinforced-Concrete Chimneys, Silos, Bins, Elevators, Tanks and Turbine-Foundations." In this Section, the writer discussed the proposal of *Reimbert*, Silos, Theorie et Pratique (Eyrolles, Paris). Reimbert suggests the installation of a cylindrical, *perforated* vertical pipe within the bin to insure uniform flow of material. Due to the perforations in this pipe, no arching can take place between the pipe and bin walls, yet the funneling effect is directed in such a fashion that it insures a uniform descent of the stored material within the bin.

PAUL ROGERS, *Consulting Engineer*
Chicago, Illinois

Atomic Industrial Forum of 1957

In our December issue we published certain of the papers presented before the 1957 Atomic Industrial Forum.

Power Reactor Program in Review

A fourteen paper session on the Power Reactor Program was one of the major features of the Forum.

"Pennsylvania Power and Light Company Project" by **W. E. Johnson,** Westinghouse Electric Corp., known as PAR has been in existence for almost two and a half years. During this period it has grown from a small group of 6 to 10 Westinghouse and Pennsylvania Power & Light engineers equipped with pencils, paper, and many ideas to an integrated group of 115 technical people supplied with about $2 million worth of experimental test facilities and a much better appreciation of the realism or lack of realism of many of its original ideas.

By the end of this year the Project will have spent $5.5 million toward determining the technical and economic feasibility of a large aqueous homogeneous reactor for central station application. All of this effort has been directed at one type—the single-region slurry reactor.

By means of plant studies and development work it is felt that the major technical problems facing this reactor have been evaluated and a real understanding of concentration control, radiation effects, flow distribution in large vessels and many others as formidable and will require considerable additional work before a firm plant design can be established. In addition, most work to date has been done using laboratory type equipment similar to a 200 gpm loop published previously and must be repeated using larger scale equipment.

Vaughn D. Nixon, Commonwealth Edison Project, then gave a "Progress Report On Dresden Station." The design and construction of this country's largest all-nuclear power plant—the Dresden Nuclear Power Station—is proceeding on schedule.

In the relatively new nuclear field, the successful completion of any large project such as the Dresden Station requires an extensive test and development program, to provide basic design information, and to develop a variety of specialized equipment and techniques. Such a program was initiated early in the Dresden Project and is presently well advanced. The recent successful operation of the G-E Developmental Boiling Water Reactor (GE BWR) at the General Electric Vallecitos Atomic Laboratory near Pleasanton, Calif., was an important milestone. This reactor, which was built to evaluate Dresden engineering, operating, and nuclear features, is currently operating under stable conditions at full power.

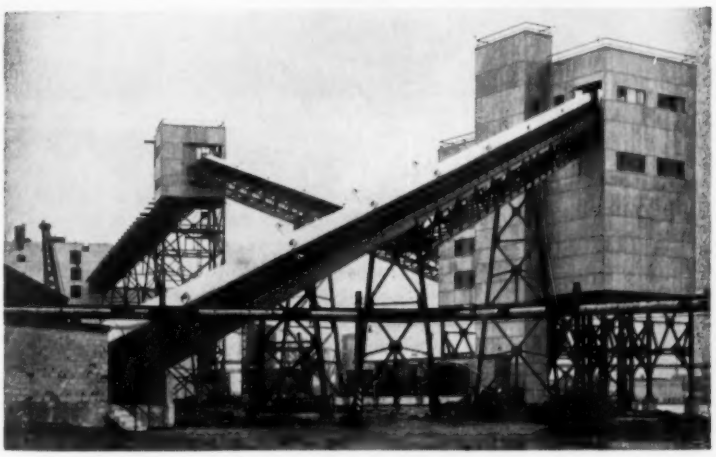
A. E. Voysey, Westinghouse Electric Corp., and **Roger J. Coe,** Yankee Atomic Electric Co., teamed up to describe the "Yankee Atomic Electric Co. Project."

The Yankee reactor is generally typical of the pressurized light water cooled and moderated reactor. However, several major innovations have been incorporated in design with the aim of approaching competitive power costs more closely than has previously been possible. The core will be an assembly of fuel rods about 0.34 in. in diameter and 7.5 ft long, arranged vertically in a square pitch lattice to form a cylindrical core roughly 6 ft in diameter. The fuel rods will contain about twenty tons of slightly enriched uranium in the form of sintered uranium dioxide pellets about 0.3 in. in diameter and about twice as long. Since there will be over a million of these fuel pellets in each loading, a reduction in the unit cost can result in substantial savings. One of the primary objectives of the research and development program is to accomplish this.

The core is contained in a carbon steel vessel which is clad internally with stainless steel and will operate at 2000 psia. Incipient or nucleate boiling will be designed for and allowed in the hotter regions of the core.

Control of the reactor at operating temperature will be accomplished by twenty-four neutron absorbing control rods. Added control to bring the reactor to cold shutdown will be provided by a soluble poison, probably boric acid, which may be circulated through the core with the coolant water. Investigation of this procedure and its effect on reactor materials and operation is another major aspect of the research and development program.

This system of spherical containment with access from below and independently supported internal structure eases the problems of construction considerably. The plan is



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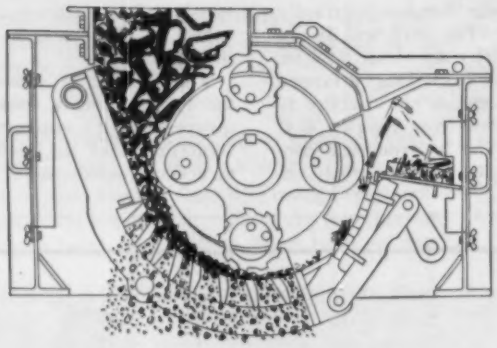
to erect only the lower section of the sphere before proceeding with the internal work.

Robert Kettner, Westinghouse Electric Corp., then described the "Westinghouse Electric Corp.—Duquesne Light Co. Project." At the beginning of this month, October 6, the Shippingport pressurized water reactor received its first core. Testing programs swung into high gear this last summer. The initial fill of main coolant loops leading to hydrostatic testing of these loops was carefully meshed with final phases of reactor plant construction. On August 22 the hydrostatic tests culminated when a pressure of 3750 psi in the primary system designed for 2500 psi was attained and held for 30 minutes. During September the plant was tested at operating temperatures and pressures using a mechanical filter in place of the core in order that any foreign material which might have been inadvertently left in the primary system could be removed. It is significant to note that at the end of these tests no evidence of any dirt was found in the system and therefore the plant is felt to be clean.

"Nuclear Development Corp. of America-Chugach Assn., Inc. Project" by **Leo Malin,** Nuclear Development Corp. of America, pointed out that this program at its origin envisioned three distinct phases: (1) initial research and development, (2) final development and detailed engineering, and (3) construction and startup. The proposal was accepted by the Commission, who issued a contract to NDA for the Phase I Research and Development work.

Since the SDR utilizes sodium as the coolant and D_2O as the moderator, it is of prime importance in establishing the safety of this reactor to (1) establish the mechanical integrity of the design, and (2) develop a suitable barrier between the sodium and water to eliminate contact should a failure develop in either the sodium or D_2O systems. The initial Research and Development contract, therefore, was oriented to assure conformance with these requirements. NDA is actively executing this program; completion is scheduled for June 30, 1958, at a budget of $1,750,000. Some months prior to this completion date, consideration will be given to planning for the Phase II program so that a smooth transition can be made from this Phase I program into the more comprehensive Phase II program.

CRUSHING COAL TO EXACTING SPECIFICATIONS



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Personals

For their paper, "Predicting Performances of Large Steam Turbine-Generator Units for Central Stations," **Robert L. Bartlett** and **Heinrich Hegetschweiler,** both General Electric engineers, have won the Prime Movers Committee award of The American Society of Mechanical Engineers. The award is made for outstanding published contributions to the literature of thermal electric station practice or equipment.

The M. W. Kellogg Co. recently announced the election of **Dr. Alex G. Oblad** as a vice president in charge of research and development activities. Dr. Oblad has devoted his professional career to petroleum and petrochemical research and development and prior

to his joining Kellogg, was vice president in charge of research and development and on the board of directors of the Houdry Process Corp., Philadelphia.

Western Precipitation Corp. has announced an important promotion within its organization to meet the expanding sales of its Dualaire jet-cleaned filter type dust collectors. **Mr. D. B. Perlis,** technical and sales engineer, has been named product sales manager in charge of coordinating Western Precipitation's world-wide Dualaire sales.

Louis C. Bishop has been named district manager for the Pittsburgh sales office of Hagan Chemicals & Controls, Inc., and will direct Hagan's sales of its instruments and control system, Calgon's industrial chemicals and Hall Labs' consulting services in the Tri-state area and most of western Pennsylvania.

John Blizard, director of research for the Foster-Wheeler Corp., has won the 1957 Percy Nicholls Award for achievement in the field of solid fuels, and was presented with this at a banquet at the Chateau Frontenac at the Joint Solid Fuels Conference of the ASME, AIME and the Canadian Institute of Mining and Metallurgy. Mr. Blizard was cited for his many contributions to advanced practice in fuel utilization and heat transfer, and for the research he has directed on radiant superheaters, pulverizer design, twin-furnace and forced circulation steam generators and heat exchangers for oil refining. He holds many patents on his work.

Charles R. Claxton, who has worked on atomic energy projects for Stone & Webster Engineering Corp. since 1954, has been named assistant chief engineer of the firm's nuclear projects division. Mr. Claxton has been project engineer in charge of the architect-engineering services being supplied by Stone & Webster to Westinghouse Electric Corp. in connection with the design of the Pressurized Water Reactor project at Shippingport, Pa.

The Green Fuel Economizer Co. recently announced the following changes in corporate officers: **Allan Davies,** formerly president becomes chairman of the board; **Bernard de Turenne** becomes president and treasurer; **Gert V. Eiserman,** former sales manager becomes vice president in charge of sales; **Russell H. Kraft** is named vice president in charge of engineering; and **Donald S. Gordon** is named vice president of the contract division with offices in Baltimore.

Arthur W. Johnson has been named manager of Ashcroft Gauge products, and **Jack E. Cox,** manager of product

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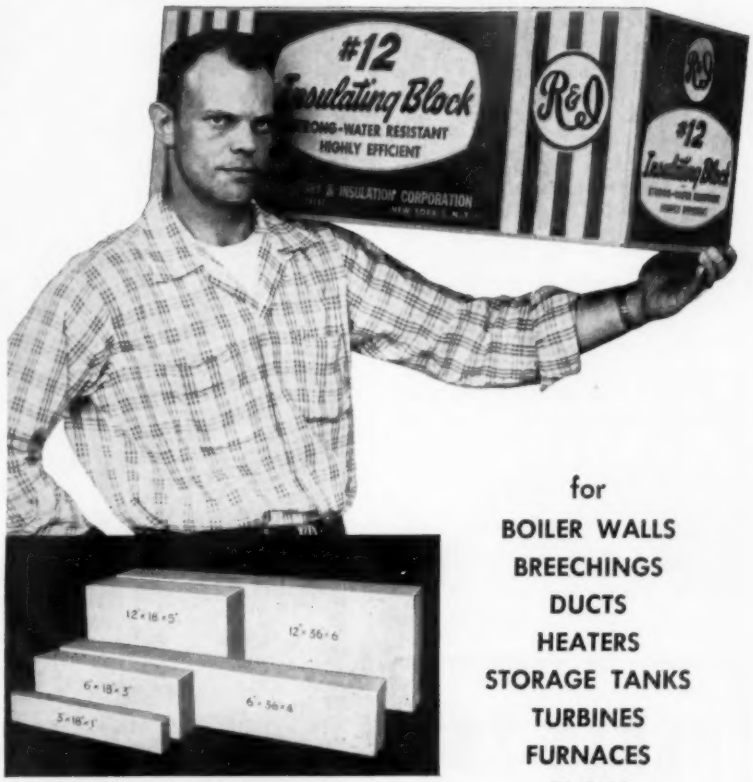

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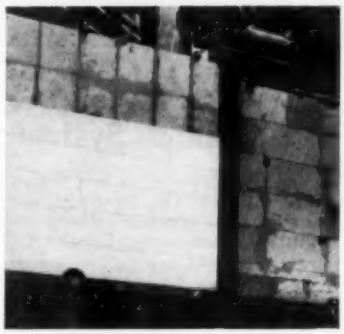

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planning, Consolidated Ashcroft Hancock division, Manning, Maxwell & Moore, Inc., recently announced.

Dravo Corp. has recently announced the appointment of **Philip J. Berg** as sales manager, engineering and construction department of its machinery division. Mr. Berg will direct the sale of this department's products and services.

Thomas M. Nourse, formerly Pittsburgh district manager, has been named head of central station sales for Hagan Chemicals & Controls, Inc. In the newly-created post, Mr. Nourse will direct sales of Hagan control systems and instruments in the utility power plant field.

Western Precipitation Corp. has announced the appointment of **Edward R. Lawlor** as product sales manager for their sales of Multiclone dust collectors. In his new duties Mr. Lawlor will be responsible for the coordination and distribution of technical, engineering and sales data to all Multiclone field personnel, for cooperation with the field personnel and agents in the engineering and installation of Multiclone applications and in the development of new uses for the equipment.

Donald T. Bixby has been named assistant manager of the standard products division of the De Laval Steam Turbine Co. Mr. Bixby joined De Laval in 1945 and has been sales manager of the division since 1955.

J. F. Roberts, director of engineering, Allis-Chalmers Industries Group, and a vice president of the company, retired as of December 31. **R. C. Allen,** director of mechanical engineering, will, in addition to his previous duties, be responsible for all consulting services in processing, welding and other phases of engineering. **W. M. Terry, Jr.,** chief engineer at Allis-Chalmers Pittsburgh Works, has been named to the new position of director of engineering coordination and will be responsible for the coordination of engineering development and for the computer and standards section.

Appointment of **Russell W. Miller** as manager of sales, Region Four, for General Electric's large steam turbine-generator department was announced recently. Mr. Miller will be responsible for all large steam turbine-generator sales activities in the New York, East Central, and Mid-States Districts of General Electric's apparatus sales division.

Leonard M. Henderson has been appointed manager of finance and control of Westinghouse Electric Corp.'s steam division in Lester, Pa. Mr. Henderson who was manager of operations at the Westinghouse aviation gas turbine division in Kansas City, Mo., will, in his new capacity, direct the financial operations of the steam division. He will be responsible for the division's accounting, budgetary control and office methods.

Allen K. Heydrick has been appointed to the new position of education and training director of Link-Belt Co. The position has been established to coordinate and to give additional emphasis to the company's education, training and employee development programs.

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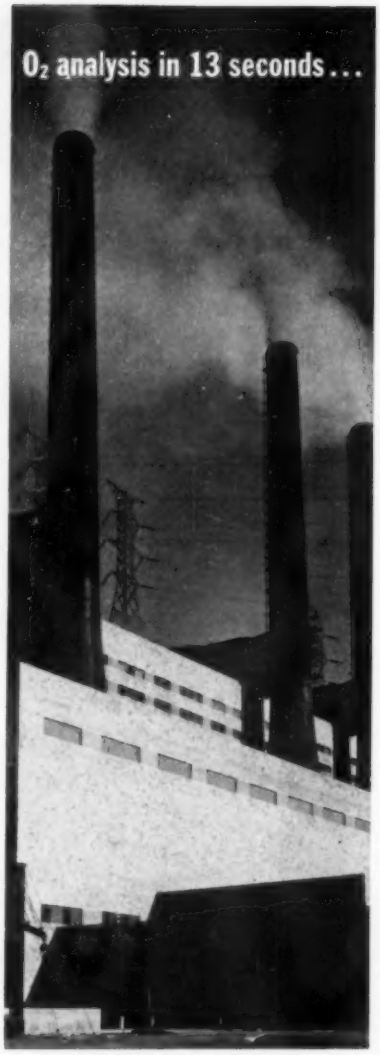

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REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

1—Statistical Mechanics

By Terrell L. Hill

432 pages *$9.00*

This book, written for graduate students and research workers in theoretical chemistry and physics, summarizes the principles of statistical mechanics at an intermediate level, and presents an organized and detailed account of certain applications of statistical mechanics which have been worked out since about 1940.

The overall aim of the author in selecting these applications has been to report the most important recent advances that have occurred and to treat each of these in great detail, rather than to give a necessarily superficial account of every topic in the entire field. Emphasis is on the theory of the applications, not on numerical calculations.

2—Maintenance Engineering Handbook

By L. C. Morrow

1528 pages *$20.00*

The long years of first-hand familiarity with the field of maintenance engineering gained by the author as chief editor of *Factory Management and Maintenance* and more recently as general chairman of the National Plant Maintenance and Engineering Conference is reflected in the selection of some 75 individual experts to cover various of the techniques, methods and procedures held by them to be most helpful in keeping production at maximum levels and yet exercising control over production costs and losses.

The bulk of the book is made up of information relative to the selection, installation, and upkeep of the kinds of equipment and services that plants must deal with; electrical, mechanical, and service equipment, transportation equipment, maintenance stores, instruments and instrumentation, and welding. In addition the author attempts to give the reader an insight into the management as well as operative phases of maintenance work.

3—Manual on Industrial Water

ASTM Special Technical Publication No. 148-B, 502 pages, $6.00

This, the third and latest printing of the Manual on Industrial Water, is as always extremely welcome and a value to industry at large. Sponsored by ASTM Committee D-19 on Industrial Water, the Manual contains a complete appendix in addition to a comprehensive discussion of water, its uses, treatment, sampling, analysis and difficulties caused by it.

The appendix lists ASTM standards relating to industrial water. It contains five methods of sampling, 41 standards, four methods of analysis, three standards for methods of reporting results, six standards for methods of test, a glossary of terms, a list of industrial water requirements and a bibliography.

Included in the latest printing are seven new methods and one important revision. Two additional proposed methods are published as additional information.

4—Corrosion: A Compilation

By Dr. Mars G. Fontana

Dr. Mars G. Fontana, chairman of the department of metallurgical engineering at Ohio State University, has authored a monthly column on corrosion during the past ten years for *Industrial and Engineering Chemistry*. This book is a compilation of those columns. The articles are grouped into seven chapters (1) Nature and Extent, (2) Eight Forms of Corrosion, (3) Eight Methods for Combatting Corrosion, (4) Corrosion Testing and Evaluation, (5) Materials, (6) Environments, and (7) High Temperature Oxidation.

Practically all metals and alloys and some non-metallics used for corrosion applications are covered. The book describes methods and detailed procedures for laboratory and plant testing, and shows corrosion as a function of temperature and concentraion of acids through iso-corrosion charts.

5—Applied Metallurgy for Engineers

By Malcolm S. Burton

407 pages *$7.50*

A prior knowledge of metallurgy is not required of the reader and the author follows this approach with a treatment essentially non-mathematical. Yet the book does provide, in a single volume, a combined coverage of physical metallurgy and industrial metallurgical processes presently available. Emphasis, though, is on the background of metallurgical science essential for proper utilization of metallurgical manufacturing methods. A good balance between theory and engineering practice is achieved; diagrams and photographs of equipment implement the theory and relate it to specific manufacturing methods.

The purpose of this book, according to the author, is twofold: to develop the metallurgical principles involved in casting, metal working, welding, heat treatment, and powder metallurgy; and to study these manufacturing processes from an engineering viewpoint, including the metallurgical factors that control selection of suitable processes and the influence of the processes on the final products so as to provide information valuable in school laboratory as well as larger production applications.

6—High Pressure Technology

By Edward W. Comings

572 pages *$11.50*

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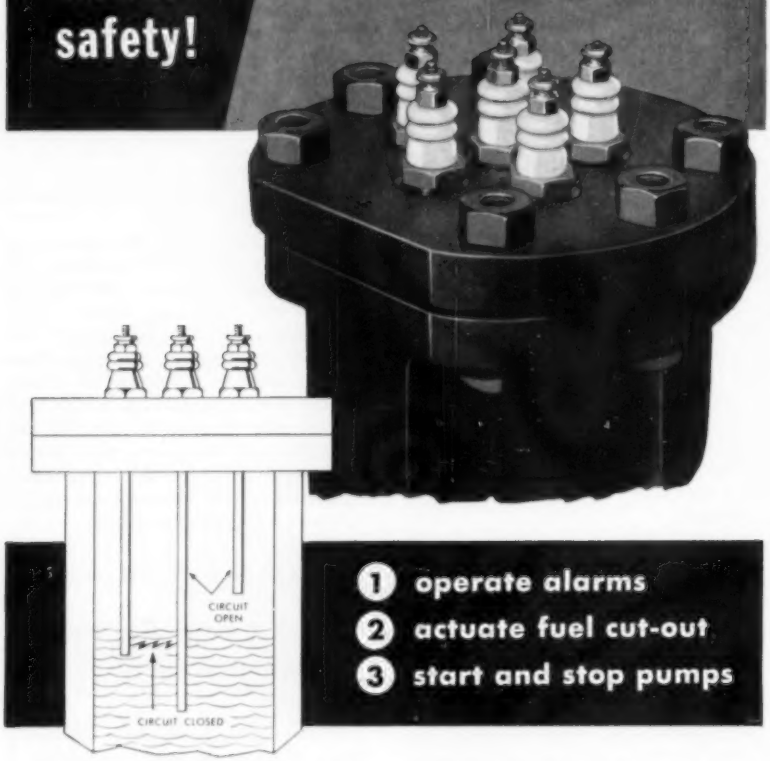

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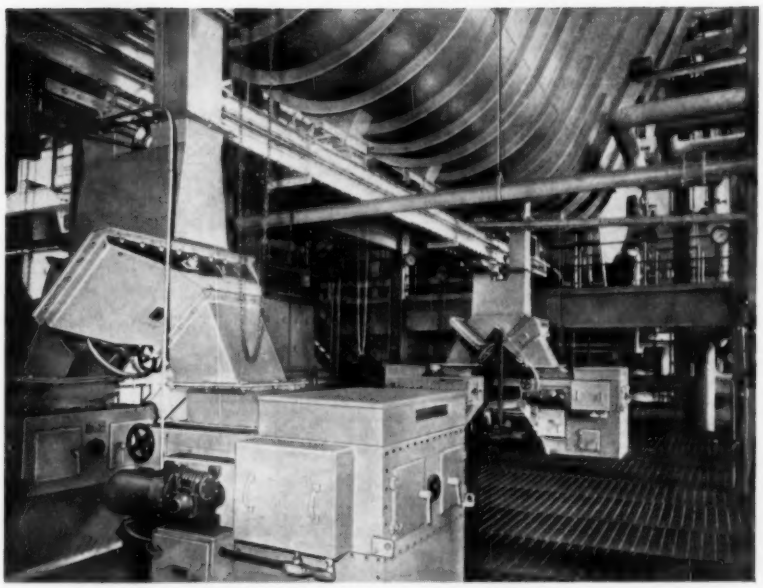

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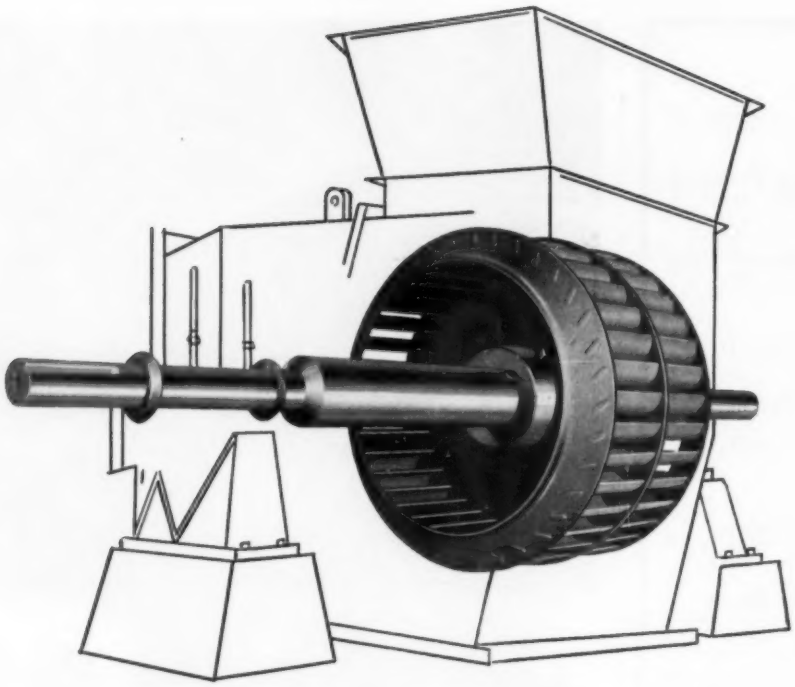

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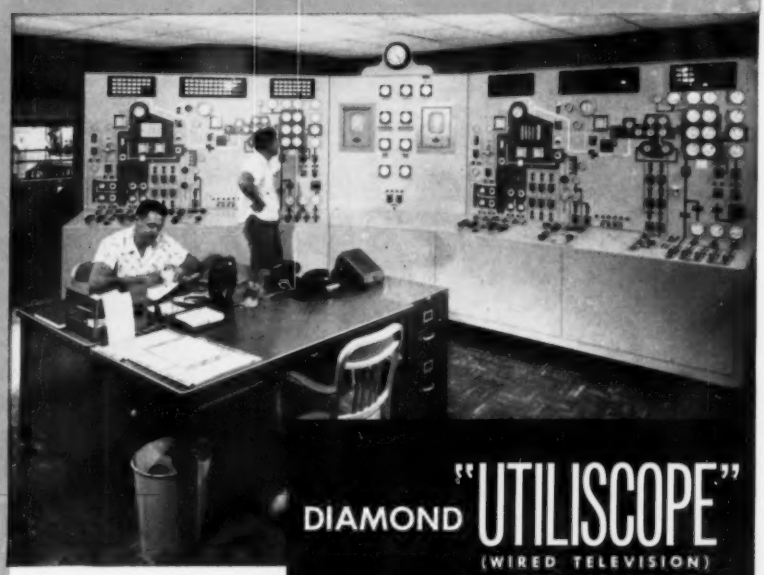

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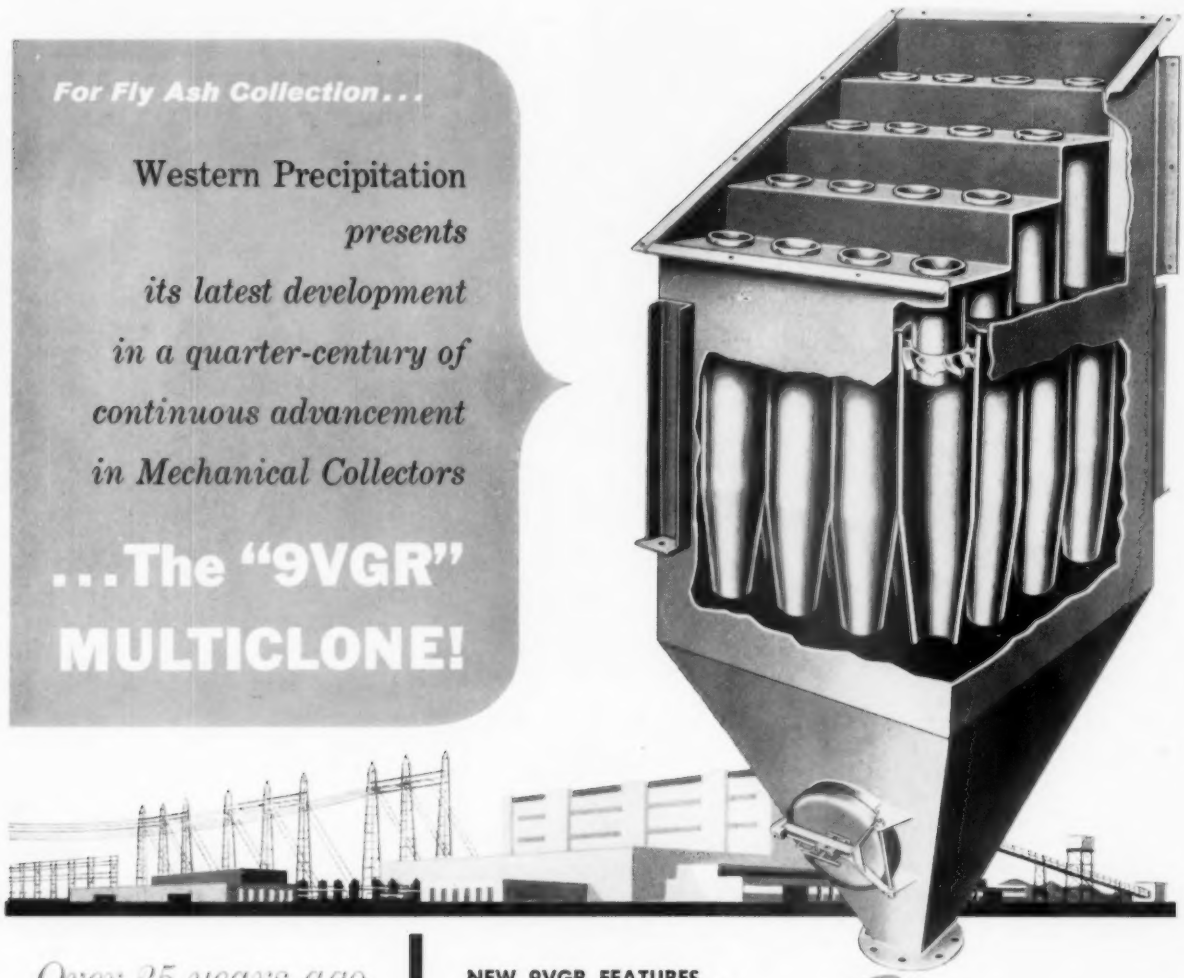

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